

# CONTRIBUTIONS TO THE DEVELOPMENT OF A POWER-SPECTRAL GUST DESIGN PROCEDURE FOR CIVIL AIRCRAFT

TECHNICAL REPORT



JANUARY 1968

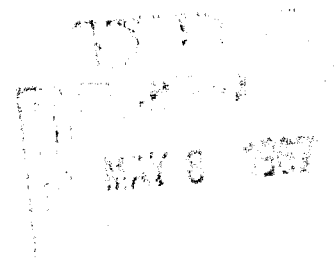
by

J.R. Fuller, L.D. Richmond, C.D. Larkins, and S.W. Russell  
(of The Boeing Company, Renton, Washington)

Lockheed-California Company  
Burbank, California  
Under Contract FA-WA-4768

for  
Federal Aviation Agency  
Aircraft Development Service

AD 651131



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## SUMMARY

This report presents a dynamic gust analysis of the Boeing Model 720B airplane and outlines two procedures for assessing gust design strength for future civil transports. This work was conducted under subcontract for the Lockheed-California Company in support of their study contract with the Federal Aviation Agency (FAA) to develop a power spectral gust design procedure for civil aircraft.

The procedures outlined are based on two approaches. The first is the design envelope approach, the second is the flight profile approach. In the design envelope approach, certain flight conditions are established by successive analyses to determine the most critical flight condition for a given portion or component of the airplane for either vertical or lateral gust loads. The one-factor level flight load added to the rms load times a particular constant will just equal the limit design strength of the component. This constant,  $\sigma_w \eta_d$ , represents an effective gust intensity which would just stress the structure to its limit design strength.

The object of the flight profile approach is to determine the expected number of flight hours that the airplane could be operated before the limit design strength of any of its major components would be exceeded. The flight profile approach requires a description of airplane operation in terms of flight profiles that best typify the airplane usage. A separate power spectral analysis is conducted for each of the profile conditions. In addition, a description of the atmosphere applicable to the condition altitude is determined. From this information, the expected number of hours required to exceed the limit strength is computed.

The 720B airplane was studied for both concepts, first, by using the bending moment on the wing, fuselage, and vertical tail as indices of their strengths. This procedure was used to locate critical flight conditions, critical portions of the structure, and to obtain preliminary values of  $\sigma_w \eta_d$  by the design envelope approach, and expected hours to fly to exceed limit design strength by the flight profile approach.

The second step was to study the more critical structural areas using a joint probability stress analysis approach developed by Boeing. The critical values of  $\sigma_w \eta_d$  and hours to fly to exceed limit design strength of each structural element in the critical area were determined. The results of these analyses indicate that the design envelope and flight profile approaches give results that are in general agreement.



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## INTRODUCTION

### Background

Gust load formulas embodying a number of simplifying assumptions have been used in the United States for over 30 years to calculate gust loads for airplanes. The underlying concept in the use of a gust formula is that measured airplane center of gravity accelerations due to continuous turbulence can be used to derive effective or derived gust velocities for specified gust shapes. These derived gust velocities for a specified gust shape, in turn, can be used to calculate the accelerations on other airplanes by reversing the process. Therefore, a gust load formula relates the peak gust induced accelerations on a given airplane to the peak accelerations expected on other more or less similar airplanes for flight through the same continuous rough air. It is clear that when newer airplanes differ significantly from past or present successful airplanes on which acceleration measurements have been made, the simple gust formula approach may not be adequate.

When a proposed airplane design or mode of operation does differ significantly from past practice, the aircraft manufacturer and the certifying agency must cope with the problem of providing adequate strength for gust loading. Ideally, the risk of exceeding the limit design gust loads per flight hour for the new airplane should be just equal to the risk of exceeding the limit design gust loads per flight hour for the older proven airplanes.

An evaluation to establish gust loads for new airplane designs should rely on rather detailed theoretical dynamic analyses that can adequately describe the behavior of the new airplanes relative to the older proven models. A generally accepted analysis technique that is used to account for differences in airplane dynamic responses and in modes of operation is power spectral analysis. The theoretical technique for using generalized harmonic analysis or power spectral analysis methods in the airplane gust loads problem have been developed and summarized by the National Aeronautics and Space Administration, (NASA). (1,2)\*

The contracting agency, Federal Aviation Agency, (FAA), has assumed that the manufacturers of given airplanes can best analyze their own designs, since they are most familiar with the developmental wind tunnel and structural testing, the detailed construction, and the manner in which the airplanes have been used in day by day service. After an evaluation

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\*Numbers in parentheses refer to items in the list of references.

of detailed proposals submitted for this study, the FAA contracted with the Lockheed-California Company, Burbank, California, to study the Lockheed Electra, Model 188, a medium weight, straight wing, 4-engine, turboprop airplane and the Lockheed Constellation, Model 749, a medium weight, straight-wing, 4-engine, reciprocating engine airplane. In addition, the FAA arranged to have The Boeing Company, Airplane Division, participate in the study under a subcontract with Lockheed to conduct a study of the Boeing Model 720B, a medium range, swept wing, 4-engine, jet transport airplane. A view of the 720B airplane in flight is shown in Fig. 1.

#### Approach

Even though the basic power spectral technique is well defined, the problem of establishing specific gust design levels for new airplanes requires that a concerted effort be made to establish the relationship between the stresses induced in critical structural elements of existing successful airplanes and the design strength of these elements. In this manner, an estimate can be made of the expected number of flight hours that proven airplanes can be expected to operate before the limit design strengths of their various structural elements are exceeded. This approach requires an intimate knowledge of the airplane usage, and is commonly referred to as the flight profile approach. A second approach involves computation of the statistical probability of exceeding the limit strengths of critical structural elements when the airplane . being flown in a manner to most highly stress that portion of the airplane containing the critical elements. The level of gust intensity at a given altitude that would just stress the structural element in question to its limit strength provides a measure of gust intensity that might logically be used on a new design for the same altitude. This second approach is referred to herein as the design envelope approach. Both of these approaches are exercised in the analyses that follow.

The approach of establishing gust design levels for new airplanes by strength analyses of older successful airplanes raises the question of sensitivity of the analysis procedure to the various parameters used in the analyses. Therefore, the results are studied to determine the sensitivity of the analyses to variations in aerodynamic parameters, the mathematical model, and in assumed airplane usage.

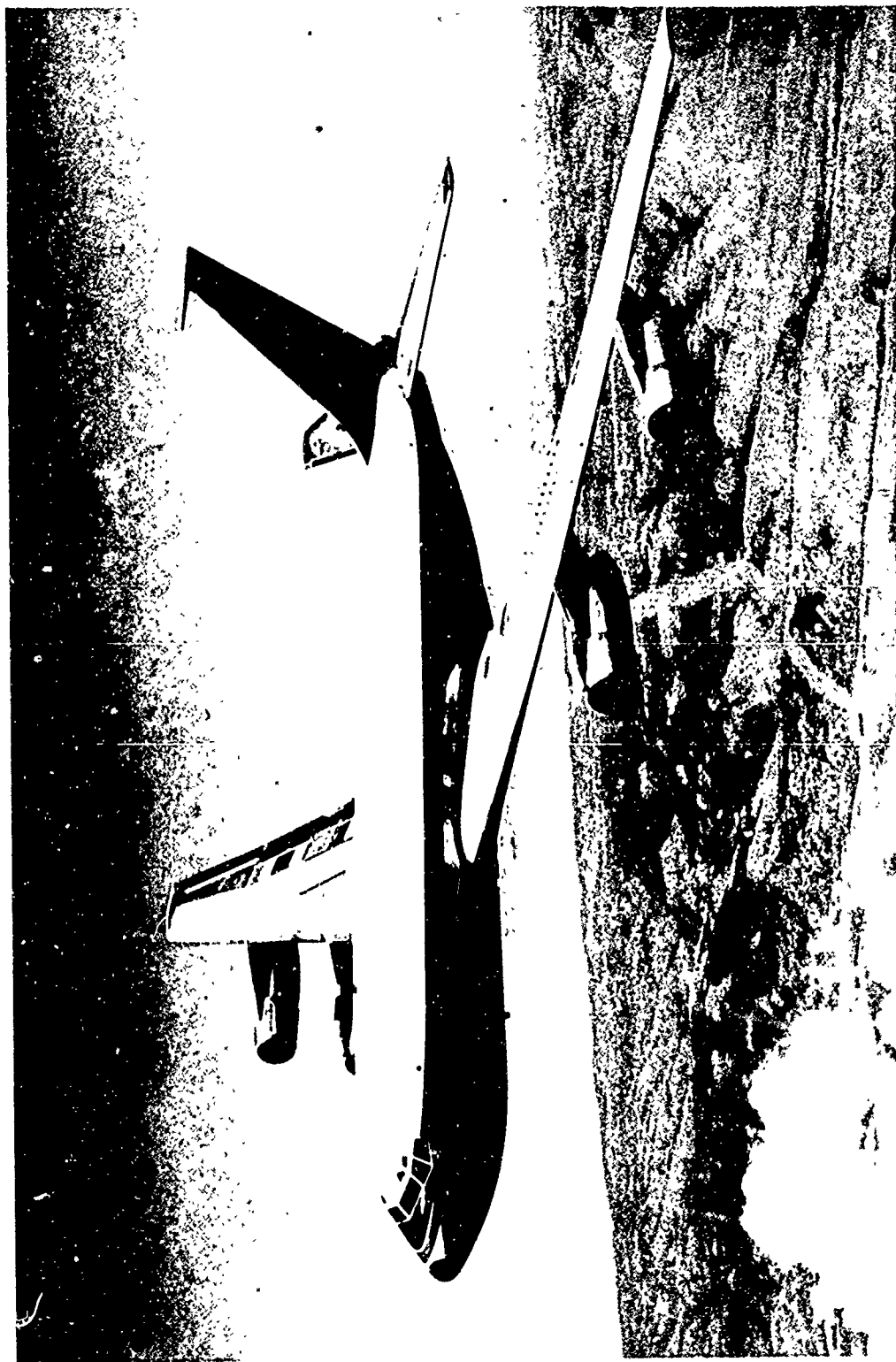


FIGURE 1. 720B AIRPLANE

# NOMENCLATURE

|                                              |                                                                                          |
|----------------------------------------------|------------------------------------------------------------------------------------------|
| $x, \xi$                                     | Shear stress, psi                                                                        |
| $y, f$                                       | Axial stress, psi                                                                        |
| $x_0, \xi_0, y_0, f_0$                       | Steady stress values, shear and axial stress, respectively, psi                          |
| $F_\xi$                                      | Allowable shear stress, psi                                                              |
| $F_t$                                        | Allowable axial stress, psi                                                              |
| $\bar{Z}$                                    | Stress vector,                                                                           |
| $\dot{\bar{Z}}$                              | Stress velocity vector,                                                                  |
| $\sigma_x, \sigma_y, \sigma_a, \sigma_\beta$ | Root mean square values (standard deviations) for $x, y, a$ , and $\beta$ , respectively |
| $\phi_x(\omega), \phi_y(\omega)$             | Power spectral density functions for random process $x(t)$ and $y(t)$ , respectively     |
| $\phi_{xy}(\omega)$                          | Cross power spectral density function for $x(t)$ and $y(t)$                              |
| $\omega$                                     | Circular frequency, rad. per sec.                                                        |
| $\rho$                                       | Correlation coefficient for $x(t)$ and $y(t)$                                            |
| $a, \beta$                                   | Time rate of change of $x$ and $y$ , respectively                                        |
| $p(x), p(y)$                                 | Probability densities of $x$ and $y$                                                     |
| $p(x, y)$                                    | Joint probability density of $x$ and $y$                                                 |
| $f(x, a, y, \beta)$                          | Probability density of $x, a, y, \beta$                                                  |
| MS                                           | Margin of safety                                                                         |
| $P(MS < 0)$                                  | Probability that MS is less than zero or percent time that MS is less than zero          |



|                          |                                                                                                                             |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| $P(MS \geq 0)$           | Probability that MS is greater than or equal to zero                                                                        |
| $C$                      | A curve on xy-plane                                                                                                         |
| $\bar{N}$                | Unit vector normal on $C$                                                                                                   |
| $[ ]$                    | Column matrix                                                                                                               |
| $[ \ ]$                  | Row matrix                                                                                                                  |
| $N_C$                    | Total number of passages across an arbitrary curve per second or per foot traveled                                          |
| $\sigma_w, \sigma_v$     | Root mean square gust velocity, ft. per sec.                                                                                |
| $\hat{f}(\sigma_w)$      | Probability density distribution of $\sigma_w$                                                                              |
| $V$                      | Velocity, ft. per sec.                                                                                                      |
| $\bar{G}$                | Expected exceedances of limit design strength per hour                                                                      |
| $\bar{A}_f, \bar{A}_\xi$ | Root mean square stress response for $\sigma_w$ of unity, psi per ft. per sec.                                              |
| $N_0$                    | Number of times per unit time or distance that a time-history crosses its mean value with positive slope; or negative slope |

## DESCRIPTION OF THE ATMOSPHERE

### Gust Power Spectrum

Certain statistical estimates for loads, accelerations or stresses for flight vehicles can be obtained by generalized harmonic analysis techniques if sufficient statistical information is available for the random forcing environment. If it can be assumed, as has been done for the current study, that (1) the turbulence is essentially frozen and the airplane penetrates or passes over the turbulence much as an automobile would travel a rough road, and (2) if it is assumed that the spanwise effects of the turbulence are not of major importance, then a one-dimensional power spectral approach is adequate.

If it is further assumed that the turbulence is isotropic; that is, statistically invariant for any rotation or translation of the coordinate axis system; then, a single power spectral density function can be used for separate vertical and lateral analyses for a given flight condition. The assumption that there is no significant aerodynamic or inertia coupling between vertical and lateral airplane degrees of freedom is made when it is assumed that separate or uncoupled vertical and lateral dynamic analyses will suffice. All of these rather restrictive assumptions have been made for the analyses discussed herein; and a constant parameter normalized power spectral density function was chosen to represent atmospheric turbulence for all altitudes.

A meeting was held with NASA and FAA personnel at Langley Field on March 10, 1964, to discuss the atmospheric turbulence description to be used in this program.<sup>(3)</sup> These discussions resulted in the choice of an isotropic turbulence power spectral density function and NASA's consent to provide operational VGH data for the three airplane types being studied. The VGH data was provided to aid Lockheed in determining a probability distribution for root-mean-square (rms) gust velocity to be used with the selected spectrum shape. These two functions provided a sufficient atmospheric turbulence model for the overall study.

The atmospheric turbulence of spectrum chosen was as follows:

$$\phi_w(\Omega) = \frac{\sigma_w^2 L}{\pi} \frac{1 + \frac{8}{3} (1.339 L \Omega)^2}{[1 + (1.339 L \Omega)^2]^{11/6}} \quad (1)$$

A scale of turbulence, L, of 2,500 feet was selected. This spectrum shape, designated as the "isotropic turbulence," Case I spectrum, has been extensively evaluated by NASA and appears to provide a good fit to their experimentally determined gust spectra.<sup>(2)</sup> The 2,500 ft. scale of turbulence is most probably low, and would be expected to give a somewhat conservative or high number of load or stress exceedance counts per unit time. NASA's experience indicates a scale of turbulence for the above power spectrum in the order of 3,000 to 6,000 ft. A comparison of the Case I spectrum shape chosen for this study, and the commonly used Case II isotropic turbulence spectrum with a scale of turbulence of 1,000 ft. is shown in Fig. 2.

#### Distribution of RMS Gust Velocities

The power spectral analysis approach used herein is applicable only to stationary Gaussian continuous turbulence, but atmospheric turbulence is not statistically stationary or Gaussian over long distances. The statistical quantities used to describe turbulence vary with altitude, wind condition, terrain roughness, temperature gradient, season of the year, and a host of other variables. However, it has been observed that the power spectrum shape from 1,000 to 40,000 ft. above the terrain is reasonably invariant. As a result, NASA has proposed that atmospheric turbulence be considered locally Gaussian and stationary and that the total experience of flying through rough air be considered to be made up of a range of exposures to turbulence of various intensities all using the same shape power spectrum. Thus, they have proposed that a statistical distribution of rms gust intensities be considered.<sup>(1)</sup> The proposed probability density function for rms gust velocity is,

$$\hat{f}(\sigma_w) = \frac{P_1}{b_1} \sqrt{\frac{2}{\pi}} e^{-\sigma_w^2 / 2b_1^2} + \frac{P_2}{b_2} \sqrt{\frac{2}{\pi}} e^{-\sigma_w^2 / 2b_2^2} \quad (2)$$

$\frac{\phi(\Omega)}{\sigma^2}$ , NORMALIZED  
POWER SPECTRAL  
DENSITY,  $\frac{(\text{ft/sec})^2}{\text{rad/ft}}$

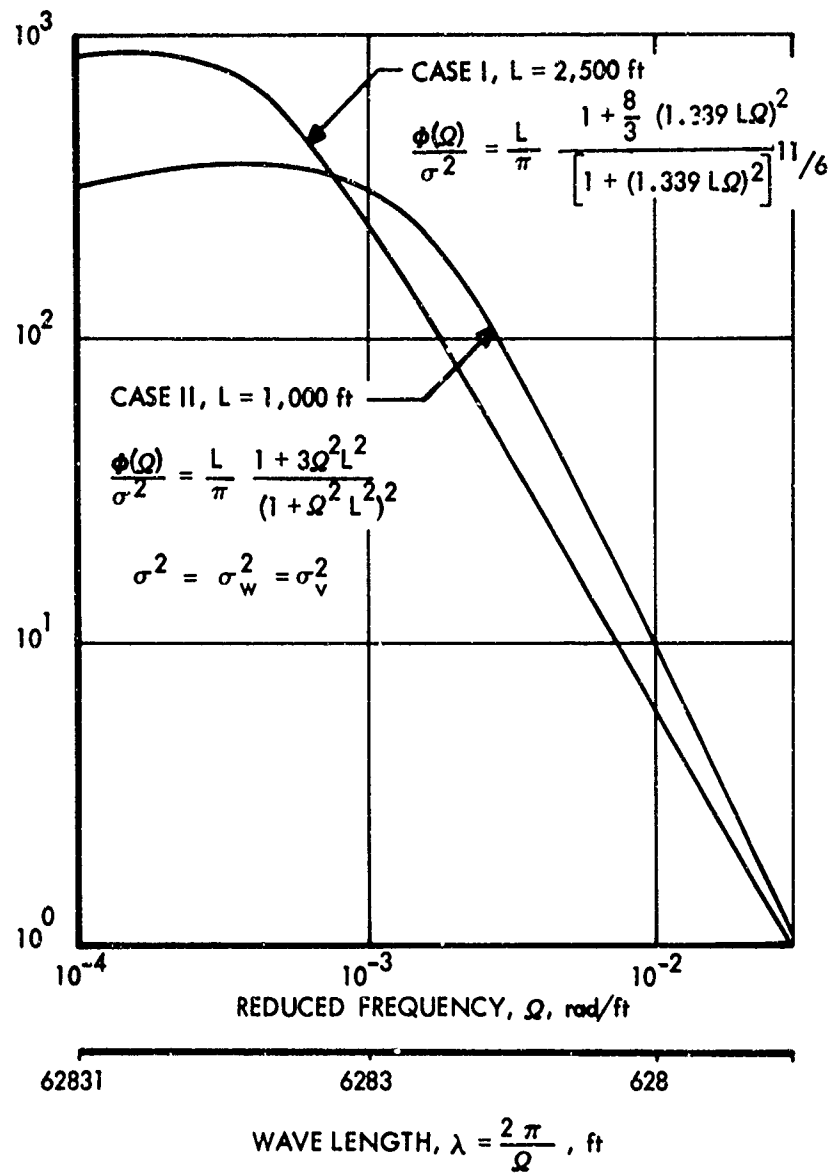


FIGURE 2. NORMALIZED ISOTROPIC  
TURBULENCE POWER SPECTRA

Eq. (2) leads to an expression for the number of times per unit time that a given load level,  $y$ , is exceeded,

$$\bar{G}(y) = P_1 N_0 e^{-y/b_1 \bar{A}} + P_2 N_0 e^{-y/b_2 \bar{A}} \quad (3)$$

where,

|            |                                                                                                                                                     |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| $N_0$      | number of times per unit time that the $y$ -time history crosses its mean value with positive (or negative) slope                                   |
| $P_1, P_2$ | fraction of time or distance flown in nonstorm (light) turbulence, and fraction of time or distance flown in storm (heavy) turbulence, respectively |
| $b_1, b_2$ | turbulence scale parameters for nonstorm and storm turbulence, respectively                                                                         |
| $\bar{A}$  | rms value for the load quantity, $y$ , per unit rms gust velocity                                                                                   |

The zero crossings per unit time,  $N_0$ , is a function of the shape of the gust power spectral density function. As a result, when a new spectrum shape is chosen, the values for  $P_1$ ,  $P_2$ ,  $b_1$ , and  $b_2$  must be re-evaluated to provide load results which agree with flight data

Lockheed investigated the turbulence parameters  $P_1$ ,  $P_2$ ,  $b_1$ ,  $b_2$  and arrived at the relationships shown in Figs. 3 and 4. These turbulence parameters were determined not only from a substantial sample of airline VGH data, but also from data obtained from military operations at higher altitudes. Most of the basic data was obtained from a summary report prepared by the Douglas Aircraft Company, Inc., Long Beach, California, under contract with the Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. (4)

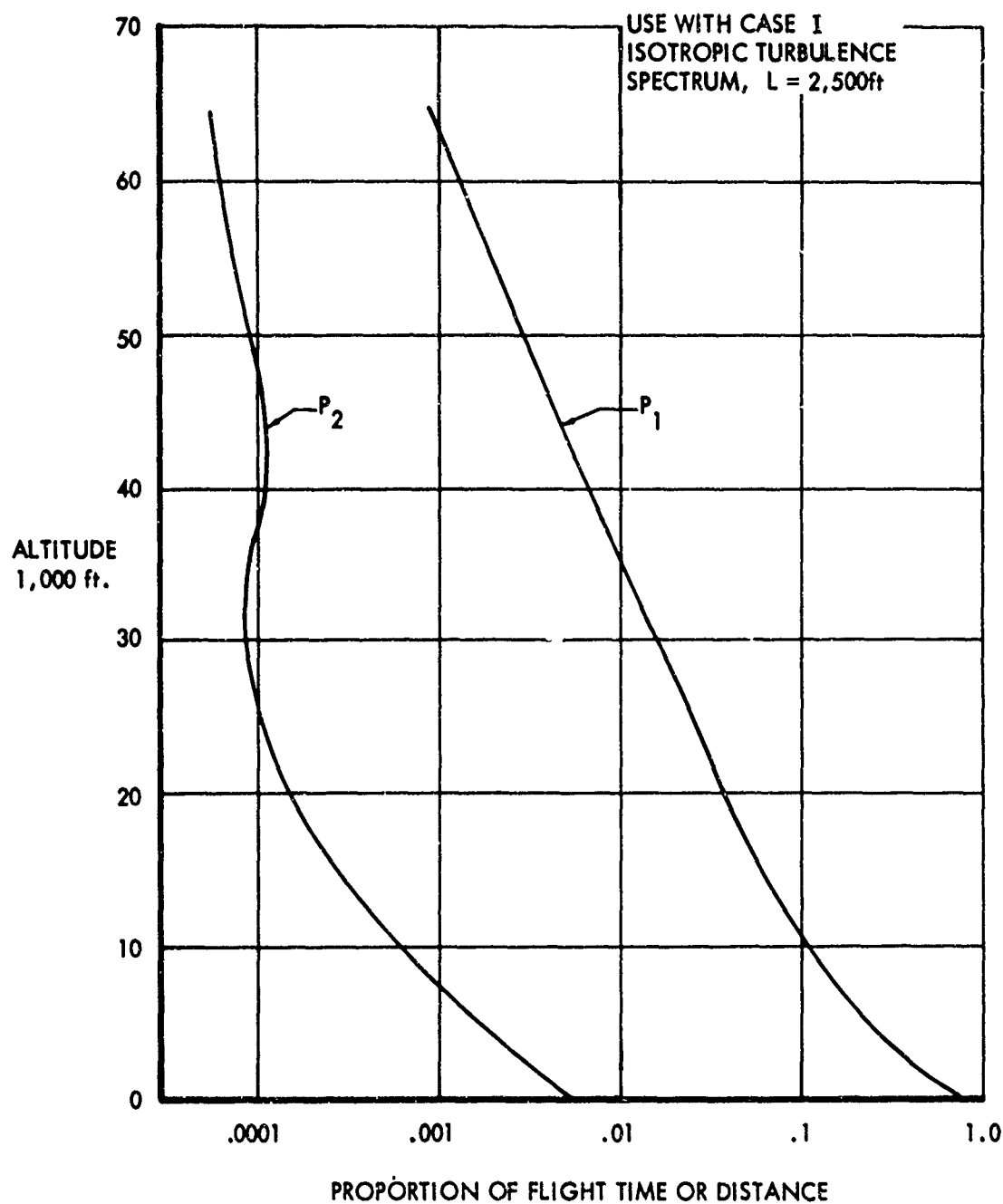


FIGURE 3. PROPORTION OF FLIGHT TIME OR DISTANCE IN STORM AND NONSTORM TURBULENCE

USE WITH CASE I  
ISOTROPIC TURBULENCE  
SPECTRUM,  $L = 2,500$  ft

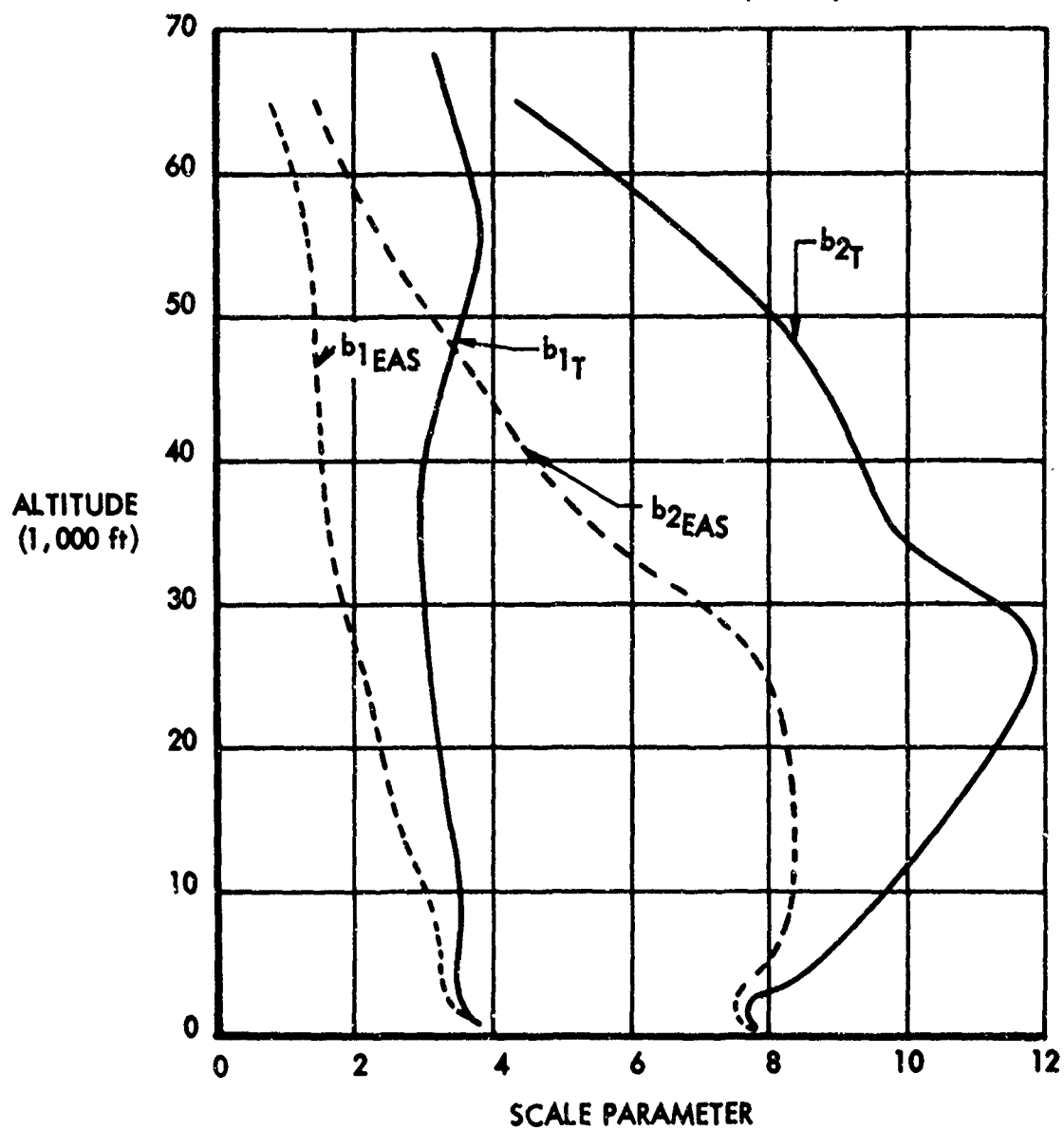


FIGURE 4. TURBULENCE SCALE PARAMETERS

## ANALYSIS CONDITIONS

### Estimated Airline Usage of 720B Airplane

The airplane configurations analyzed during this study were selected to provide statistical loads and stress information for use with two different design approaches. One approach, flight profile analysis, requires information based on actual airplane usage and reflects the speeds, altitudes, and gross weights experienced during routine airline operation. The second approach, design envelope analysis, requires the generation of statistical loads estimates for critical design points on or within the speed-altitude design envelope.

A survey of the airline usage of 720 and 720B airplanes was made to determine the airplane usage most appropriate for flight profile analysis. Three airlines, whose route structures were representative of the fleet usage, were chosen for the survey. These airlines operate a total of thirty-seven 720/720B airplanes or 30 percent of the entire 720/720B fleet. The survey consisted of compiling the usage of these airplanes in terms of the total profiles flown for particular profile lengths. The profile intervals chosen varied from 100 to 2,600 n. miles in 100 n. mile intervals. One flight profile or segment is comprised of a single takeoff, climb-out, cruise, and descent. The results of this survey are presented in Fig. 5(a) in terms of profile length as percent of the total profiles flown. A comparison of these results with the results of the NASA VGH data for 707-300 airplanes (3) is shown in Fig. 5(b). The comparison is made in terms of the percent of total profiles flown versus profile duration in minutes. It can be seen that there is a definite similarity between the operation of 707-300 airplanes and 720/720B airplanes for the shorter flights. As would be expected, the longer range 707-300 shows a greater usage over longer segments than 720/720B airplanes.

The selection of representative analysis profiles was based on a distribution of time spent on the various flights. This distribution, shown in Fig. 5(c), differs from the percent of segments flown, Fig. 5(a), because each segment was weighted by the segment flight time. The flight segment duration information in Fig. 5(c) was used to establish the representative flight profiles for the analysis of the 720B airplane.

Values of indicated airspeed versus altitude based on the NASA VGH data (3) were used for the flight profile studies. A comparison of the recommended airspeeds with the average operational speeds is presented in Fig. 6. This comparison shows that the actual operating airspeeds are less than the recommended speeds at the lower altitudes, while at the



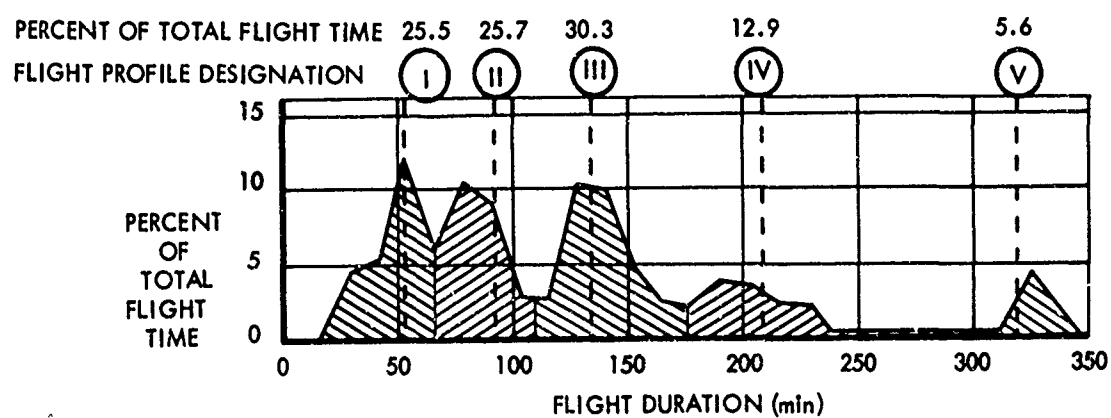
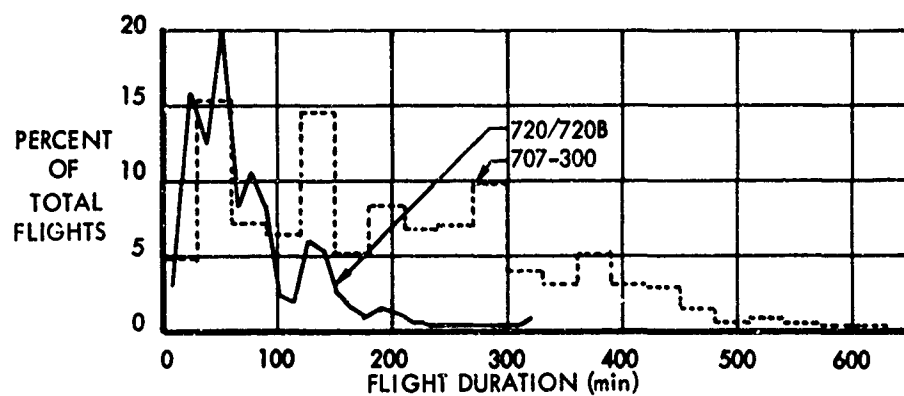
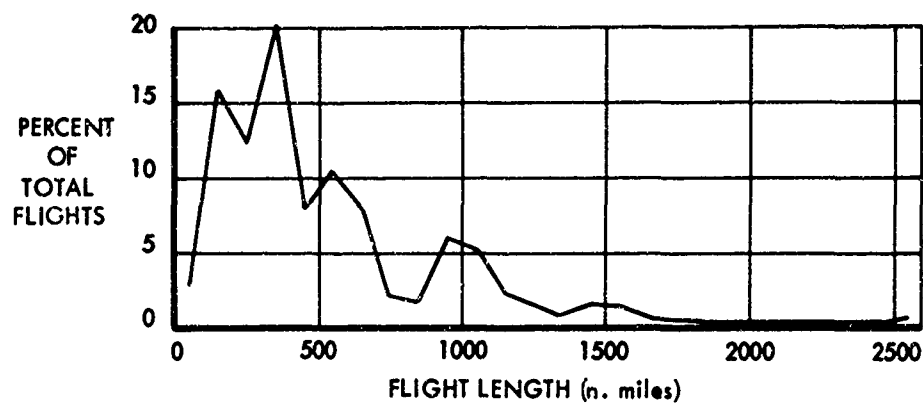


FIGURE 5. FLIGHT SEGMENT UTILIZATION, 707-300 AND 720B

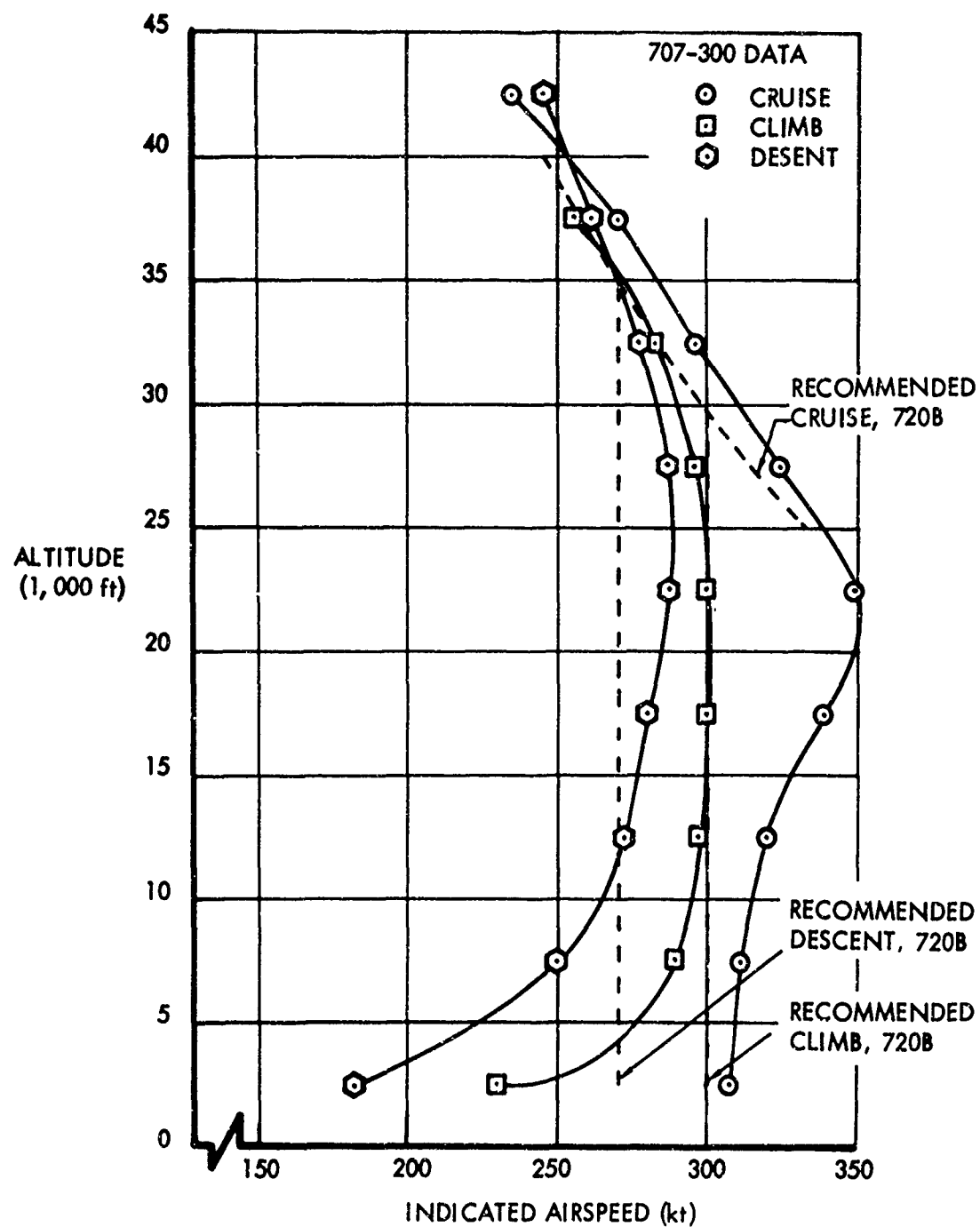


FIGURE 6. RECOMMENDED AND AVERAGE OPERATIONAL AIRSPEEDS

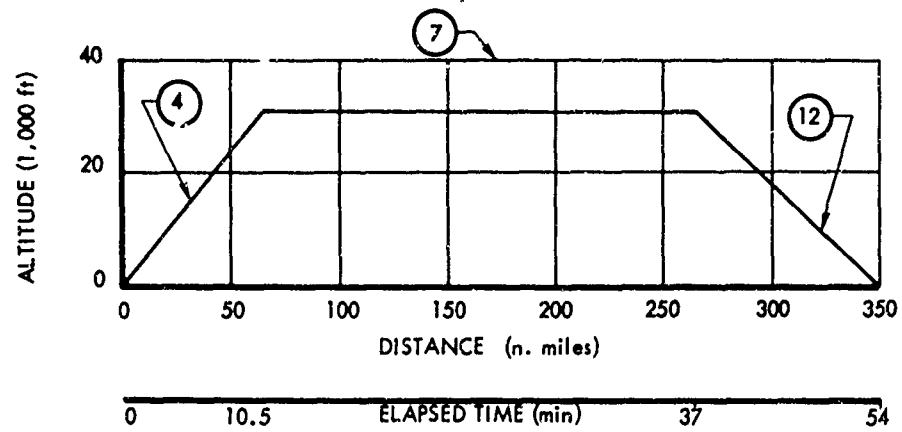
higher altitudes there is better agreement between the recommended and operational speeds. The statistical values for indicated airspeed were used in the flight profile analyses in order to be as consistent as possible with the operational experience.

#### Flight Profiles for 720B Analyses

Five profiles were chosen from Fig. 5(c) for the dynamic analyses. The five basic and alternate profiles are shown in Figs. 7 through 11. Profiles I through V have ranges of 350, 600, 1000, 1600, and 2500 n. miles for flight durations of 55, 85, 135, 205 and 325 minutes, respectively. The variations of gross weight and speed are also given in Figs. 7 through 11. The gross weight at the beginning of each flight profile is based on the prescribed fuel loading necessary to accomplish the flight plus 10,000 lb. of reserve fuel for holding or alternate field requirements. The cargo compartments were considered to be fully loaded on a space limited basis, and the passenger load factor was assumed to be 55 percent. This load factor was the 1963 average for 720 and 720B operations by United States airlines.

#### Flight Profile Analysis Conditions

A summary of the flight profile analysis conditions is given in Tables 1 and 2. Conditions 1, 2, and 3 were selected to represent the climb portion of Profile III, Fig. 9. Results from analysis for these conditions allowed a study to be made of the variations of load and stress exceedance data for climb at an average climb gross weight. Parametric variations in gross weight at the 15,000 ft. altitude, Conditions 4, 5, and 6, provided information to account for the climb portions of other profiles. Three cruise conditions, Conditions 7, 8, and 9, were selected to examine the variations in loads with cruise altitude at a constant gross weight. These points are indicated on Profile II, Fig. 8, as Options A and B, and on Profile V, Fig. 11. Two additional conditions, Conditions 10 and 11, were studied for the same 35,000 ft. altitude at different gross weights to account for the fuel burn-off during cruise. Conditions 12 and 13, for altitudes of 10,000 and 20,000 ft., respectively, were chosen to evaluate the descent. The descent portions of all the profiles are the same; therefore, the results obtained for one descent were applied to all profiles.



(n) FLIGHT PROFILE ANALYSIS CONDITION

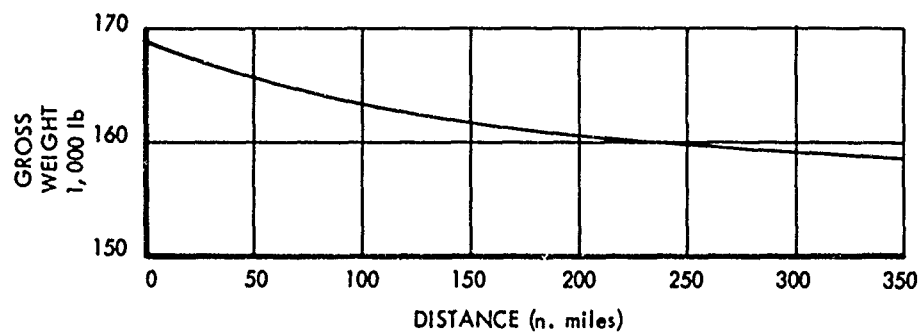
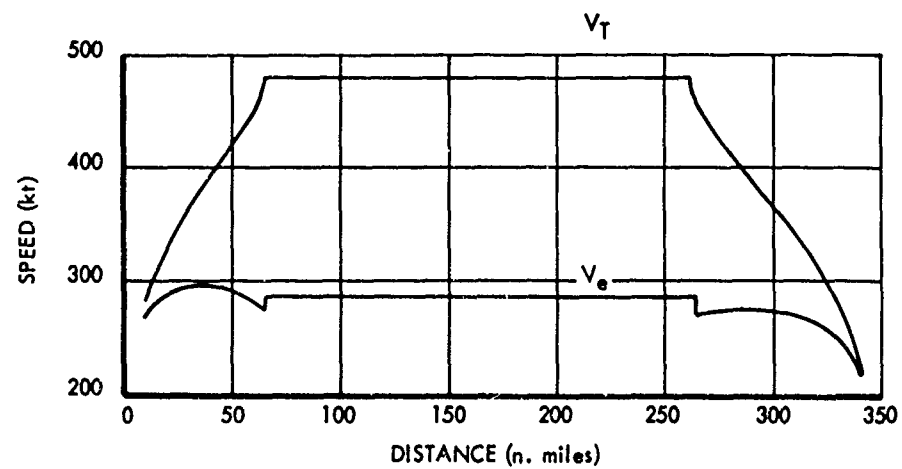
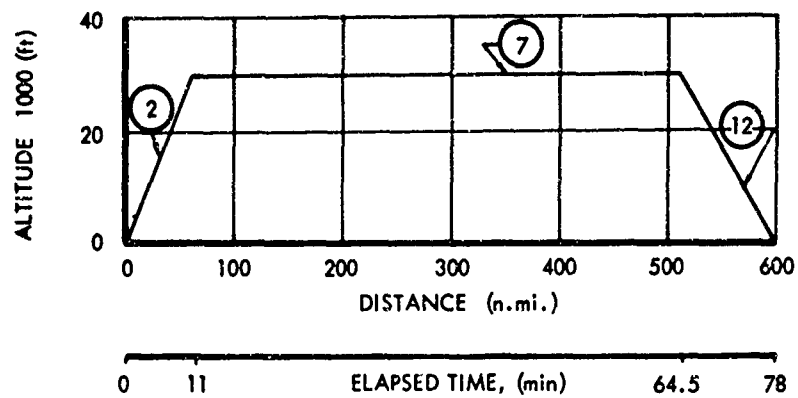


FIGURE 7. FLIGHT PROFILE I



n FLIGHT PROFILE ANALYSIS CONDITION

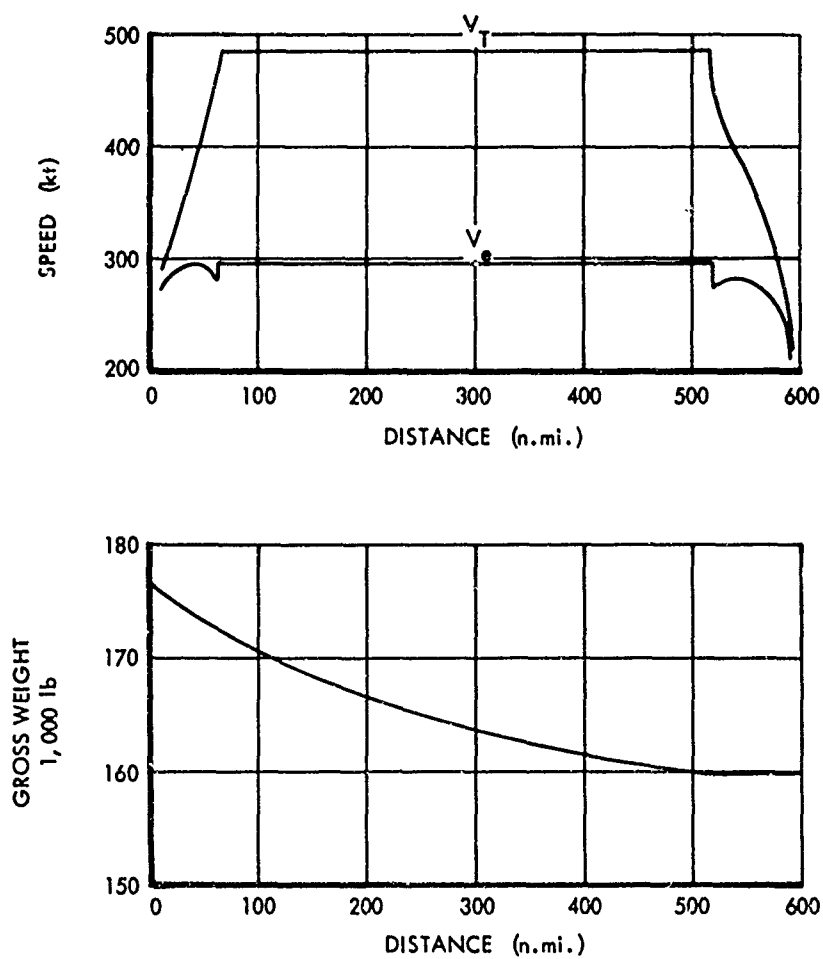


FIGURE 8a. FLIGHT PROFILE IIA

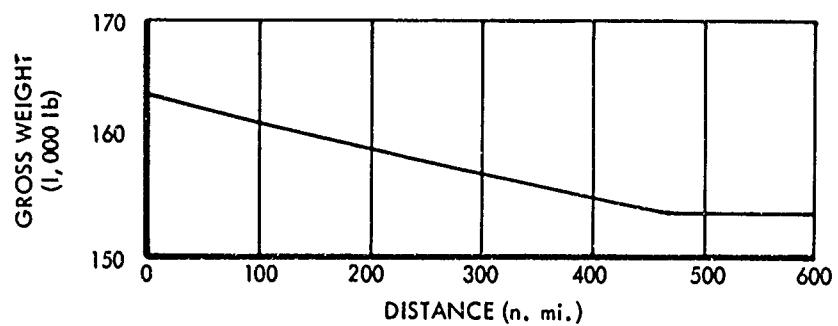
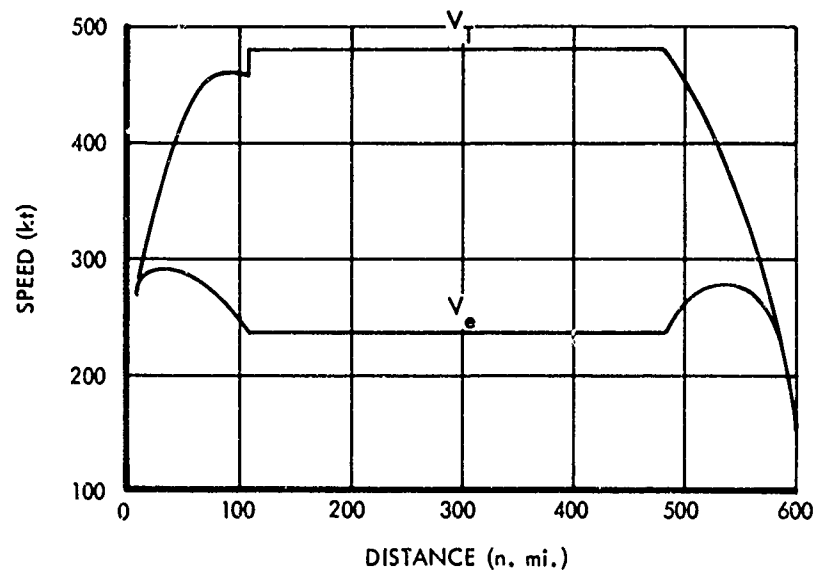
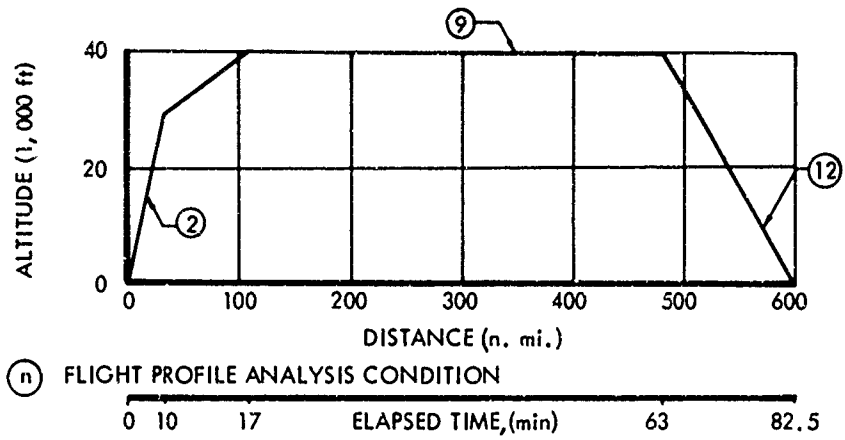
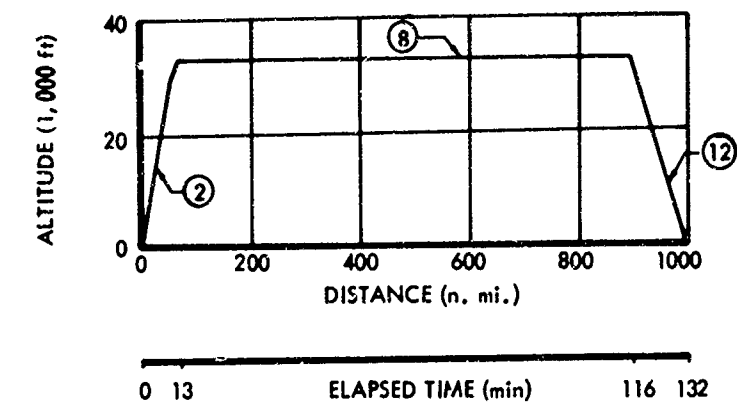


FIGURE 8b. FLIGHT PROFILE IIB



⑤ FLIGHT PROFILE ANALYSIS CONDITION

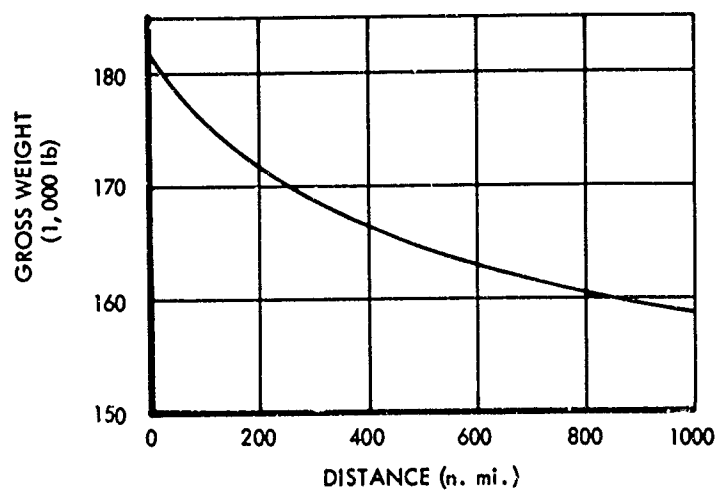
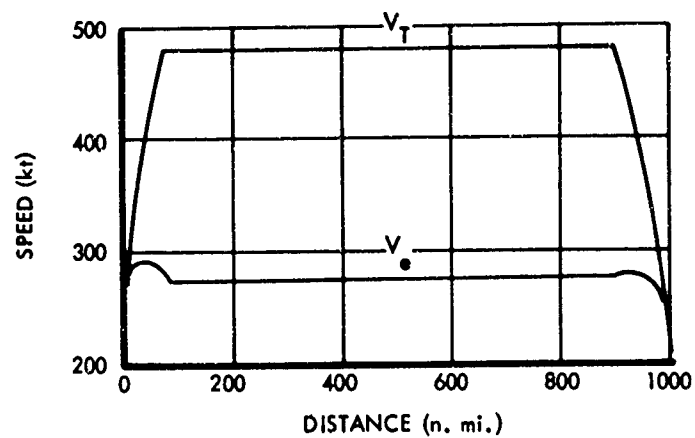


FIGURE 9. FLIGHT PROFILE III

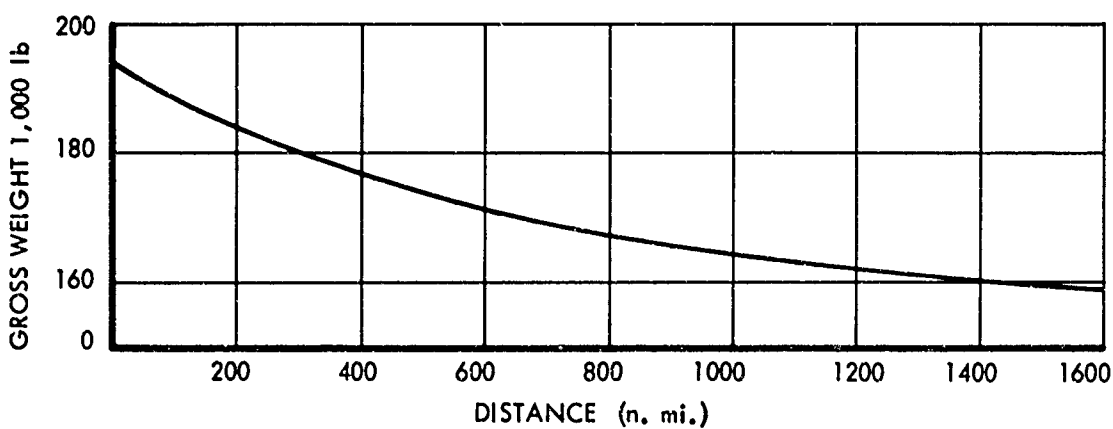
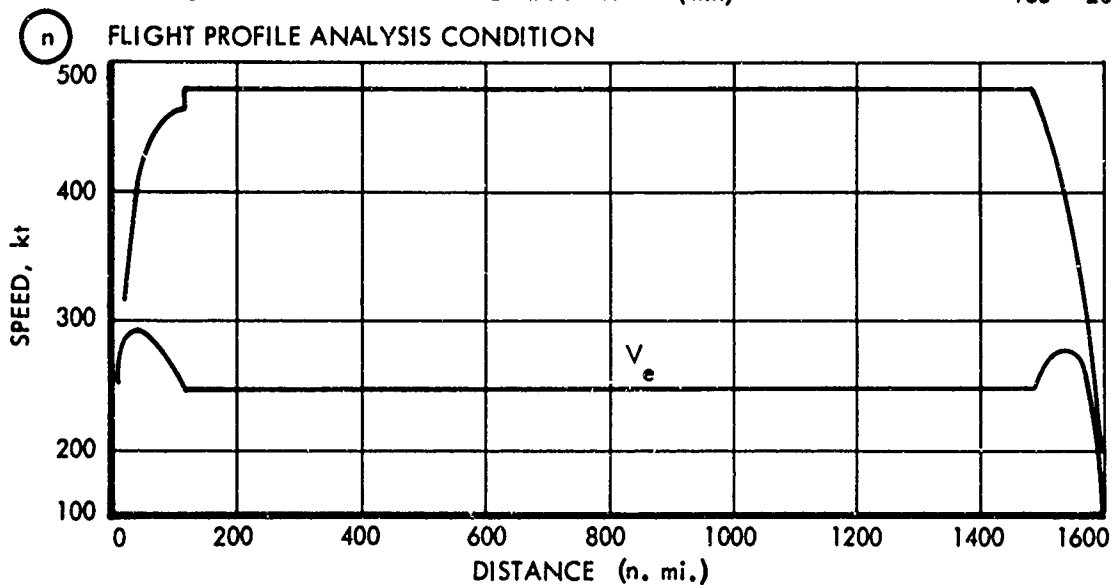
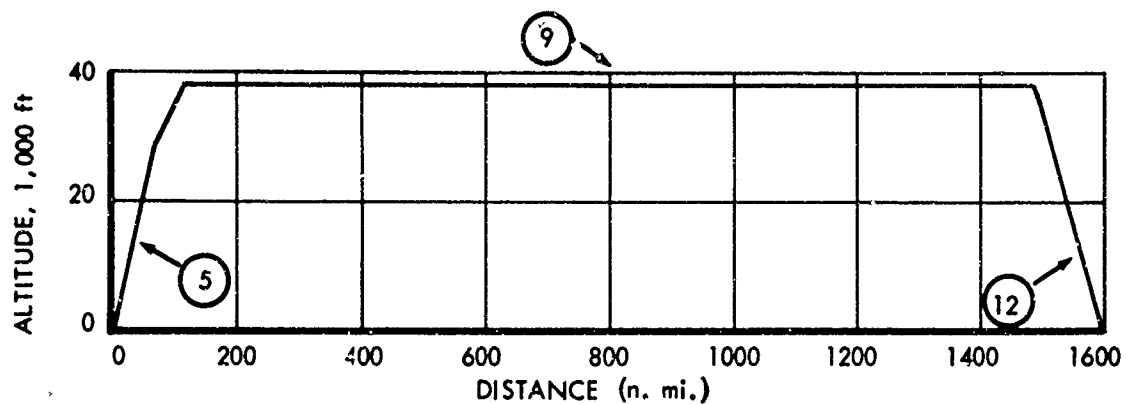
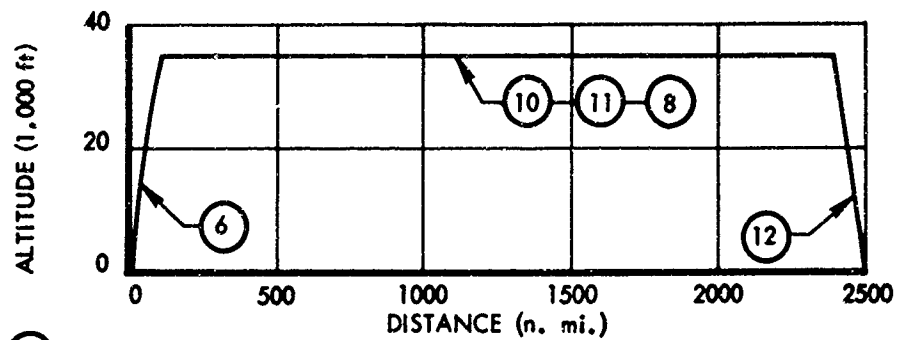


FIGURE 10. FLIGHT PROFILE IV





5 FLIGHT PROFILE ANALYSIS CONDITION

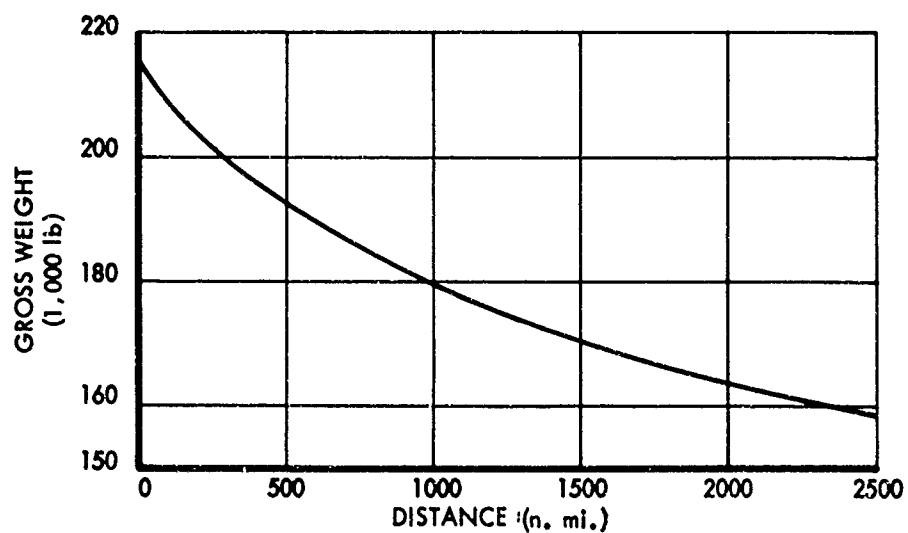
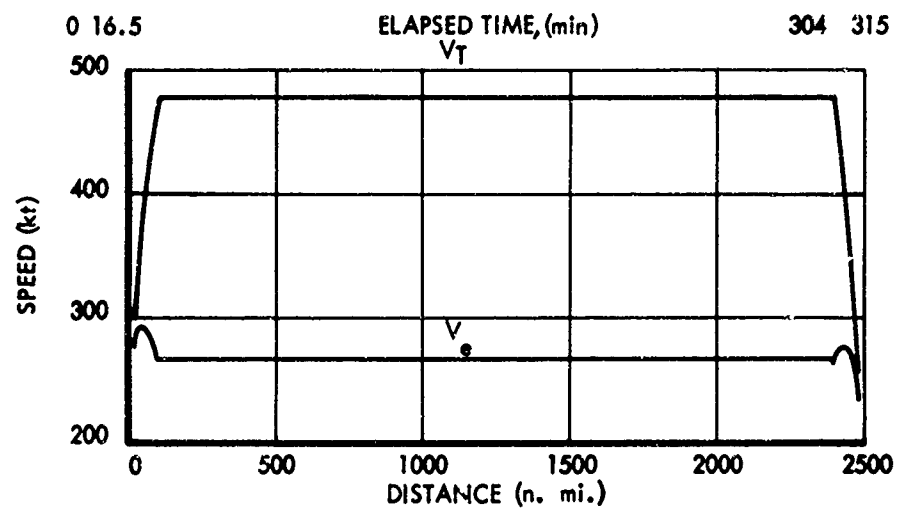


FIGURE 11. FLIGHT PROFILE V

TABLE I. FLIGHT PROFILE ANALYSES

| Flight Profile | Percent of Total Flight Time | Profile Length, N.Miles | Flight Duration, Min. | Phase                                          | Analysis Condition No.            | Condition Time, Min.                        | Condition Length, N.Miles                         |
|----------------|------------------------------|-------------------------|-----------------------|------------------------------------------------|-----------------------------------|---------------------------------------------|---------------------------------------------------|
| I              | 25.5                         | 350.                    | 52.                   | Climb<br>Cruise<br>Descent                     | 4<br>7<br>12<br>Total             | 11.<br>26.<br>15.<br>52.                    | 65.<br>198.<br>87.<br>350.                        |
| IIA            | 12.8                         | 600.                    | 79.                   | Climb<br>Cruise<br>Descent                     | 2<br>7<br>12<br>Total             | 11.<br>53.5<br>14.5<br>79.0                 | 65.<br>452.<br>83.<br>600.                        |
| IIB            | 12.9                         | 600.                    | 82.5                  | Climb<br>Cruise<br>Descent                     | 2<br>9<br>12<br>Total             | 17.<br>46.<br>19.5<br>82.5                  | 110.<br>370.<br>120.<br>600.                      |
| III            | 30.3                         | 1000.                   | 131.5                 | Climb<br>Cruise<br>Descent                     | 2<br>8<br>12<br>Total             | 12.5<br>103.<br>16.<br>131.5                | 80.<br>826.<br>94.<br>1000.                       |
| IV             | 12.9                         | 1600.                   | 206.5                 | Climb<br>Cruise<br>Descent                     | 5<br>9<br>12<br>Total             | 18.<br>170.<br>18.5<br>206.5                | 119.<br>1368.<br>113.<br>1600.                    |
| V              | 5.6                          | 2500.                   | 315.0                 | Climb<br>Cruise<br>Cruise<br>Cruise<br>Descent | 6<br>10<br>11<br>8<br>12<br>Total | 17.<br>95.3<br>95.3<br>95.4<br>12.<br>315.0 | 115.<br>761.3<br>761.3<br>761.4<br>101.0<br>2500. |
| Total          | 100.0                        |                         |                       |                                                |                                   |                                             |                                                   |

Note: These profiles are used for both vertical and lateral analyses

TABLE 2  
FLIGHT PROFILE ANALYSIS CONDITIONS

| Analysis<br>Condition<br>No. | Gross<br>Weight,<br>Lb. | Altitude,<br>Ft. | True<br>Airspeed,<br>Kt. | Indicated<br>Airspeed,<br>Kt. | Mach<br>No. | Payload,<br>Lb. | Fuel,<br>Lb. | cg,<br>Percent<br>MAC |
|------------------------------|-------------------------|------------------|--------------------------|-------------------------------|-------------|-----------------|--------------|-----------------------|
| 1                            | 181,600                 | 5,000            | 290                      | 270                           | .45         | 29,100          | 32,800       | 18.6                  |
| 2                            | 178,800                 | 15,000           | 370                      | 300                           | .59         | 29,100          | 30,000       | 17.0                  |
| 3                            | 178,800                 | 25,000           | 432                      | 300                           | .72         | 29,100          | 30,000       | 17.0                  |
| 4                            | 166,600                 | 15,000           | 370                      | 300                           | .59         | 29,100          | 17,800       | 18.1                  |
| 5                            | 191,800                 | 15,000           | 370                      | 300                           | .59         | 29,100          | 43,000       | 19.6                  |
| 6                            | 211,600                 | 15,000           | 370                      | 300                           | .59         | 29,100          | 62,800       | 20.6                  |
| 7                            | 163,800                 | 30,000           | 480                      | 310                           | .82         | 29,100          | 15,000       | 16.4                  |
| 8                            | 163,800                 | 35,000           | 475                      | 280                           | .82         | 29,100          | 15,000       | 16.4                  |
| 9                            | 163,800                 | 40,000           | 475                      | 250                           | .82         | 29,100          | 15,000       | 16.4                  |
| 10                           | 204,200                 | 35,000           | 475                      | 280                           | .82         | 29,100          | 55,400       | 21.5                  |
| 11                           | 183,000                 | 35,000           | 475                      | 280                           | .82         | 29,100          | 34,200       | 19.4                  |
| 12                           | 159,000                 | 10,000           | 310                      | 266                           | .48         | 29,100          | 10,200       | 17.0                  |
| 13                           | 159,000                 | 20,000           | 380                      | 284                           | .62         | 29,100          | 10,200       | 17.0                  |

Note: These flight profile analysis conditions are used for both vertical and lateral analyses

### Design Envelope Analysis Conditions

The design envelope analyses conditions selected initially were based on conditions used in the airplane design loads analysis (5). A summary of all design envelope conditions analyzed for the vertical and lateral analyses are given in Tables 3 and 4, respectively. The first design envelope vertical analyses were conducted for the airplane cruise speed,  $V_C$ , of 375 kt. equivalent, Mach .873, at an altitude of 22,000 ft. Four gross weight configurations were analyzed for this speed and altitude to determine the most critical condition. The conditions were operating weight empty, 119,700 lb.; maximum zero fuel weight, 156,000 lb.; fuel transfer weight, 186,000 lb.; and maximum flight weight, 221,600 lb. The conditions that were most critical were then examined at  $V_C$  speed, 375 kt. at 5,000 and 15,000 ft. and at  $M_C$  speed, Mach No. .90 at 30,000 and 40,000 ft. to obtain the load and stress variations with changes in altitude. At the critical altitudes determined from the foregoing results, three speed variations were conducted. The speeds chosen for the variations were  $V_B$ , 253 kt. EAS; 300 kt. EAS and  $V_D$ , 445 kt. EAS to Mach .95. Combining the results from the speed, altitude and weight configuration variations, the boundary of minimum margins was determined. A tabulation of the design envelope analyses conditions for the vertical analysis is given in Table 3. These conditions are also indicated on the speed altitude diagram in Fig. 12.

The design envelope conditions selected to isolate the most critical point for the lateral analyses were slightly different from those for the vertical analyses because the lateral response is not sensitive to the specific details of fuel loading. A high gross weight, which tends to give lower Dutch roll stability, was selected and six solutions were obtained at  $V_e$  for altitudes ranging from 15,000 to 43,000 ft.

Additional conditions were analyzed to evaluate the effects of other parameter variations such as wing bending and torsional stiffness, fuel loading, number and limits of discrete frequencies used in the analysis, yaw damper operation and lateral aerodynamic stability parameters. A summary to the parametric variation conditions is given in Table 5.

TABLE 3  
DESIGN ENVELOPE CONDITIONS - VERTICAL ANALYSES

| Analysis<br>Condition<br>No. | Gross<br>Weight,<br>Lb. | Altitude,<br>Ft. | True<br>Airspeed,<br>Kt. | Equivalent<br>Airspeed,<br>Kt. | Mach<br>No. | Payload<br>Lb. | Fuel<br>Lb. | cg,<br>Percent<br>MAC |
|------------------------------|-------------------------|------------------|--------------------------|--------------------------------|-------------|----------------|-------------|-----------------------|
| 14                           | 119,700                 | 22,000           | 532                      | 375                            | .87         | 0              | 0           | 20.5                  |
| 15                           | 156,000                 | 22,000           | 532                      | 375                            | .87         | 36,300         | 0           | 15.6                  |
| 16                           | 186,000                 | 22,000           | 532                      | 375                            | .87         | 36,300         | 30,000      | 16.3                  |
| 17                           | 221,600                 | 22,000           | 532                      | 375                            | .87         | 36,300         | 65,600      | 21.2                  |
| 18                           | 186,000                 | 5,000            | 403                      | 375                            | .62         | 36,300         | 30,000      | 16.3                  |
| 19                           | 186,000                 | 15,000           | 472                      | 375                            | .76         | 36,300         | 30,000      | 16.3                  |
| 20                           | 186,000                 | 30,000           | 530                      | 327                            | .90         | 36,300         | 30,000      | 16.3                  |
| 21                           | 186,000                 | 40,000           | 516                      | 260                            | .90         | 36,300         | 30,000      | 16.3                  |
| 22                           | 186,000                 | 22,000           | 359                      | 253                            | .59         | 36,300         | 30,000      | 16.3                  |
| 23                           | 186,000                 | 22,000           | 425                      | 300                            | .70         | 36,300         | 30,000      | 16.3                  |
| 24                           | 186,000                 | 22,000           | 480                      | 340                            | .79         | 36,300         | 30,000      | 16.3                  |
| 25                           | 186,000                 | 22,000           | 576                      | 406                            | .95         | 36,300         | 30,000      | 16.3                  |
| 26                           | 221,600                 | 5,000            | 403                      | 375                            | .62         | 36,300         | 65,600      | 21.2                  |
| 27                           | 221,600                 | 15,000           | 472                      | 375                            | .76         | 36,300         | 65,600      | 21.2                  |
| 28                           | 221,600                 | 30,000           | 530                      | 327                            | .90         | 36,300         | 65,600      | 21.2                  |
| 29                           | 221,600                 | 40,000           | 516                      | 260                            | .90         | 36,300         | 65,600      | 21.2                  |
| 30                           | 221,600                 | 15,000           | 319                      | 253                            | .51         | 36,300         | 65,600      | 21.2                  |
| 31                           | 221,600                 | 15,000           | 378                      | 300                            | .60         | 36,300         | 65,600      | 21.2                  |
| 32                           | 221,600                 | 15,000           | 561                      | 445                            | .90         | 36,300         | 65,600      | 21.2                  |

TABLE 4  
DESIGN ENVELOPE CONDITIONS - LATERAL ANALYSES

| Analysis<br>Condition<br>No. | Weight,<br>Lb. | Altitude,<br>Ft. | Airspeed,<br>Kt. | Equivalent<br>Airspeed,<br>Kt. | Mach<br>No. | Payload<br>Lb. | Fuel<br>Lb. | cg,<br>Percent<br>MAC |
|------------------------------|----------------|------------------|------------------|--------------------------------|-------------|----------------|-------------|-----------------------|
| 1B                           | 214,400        | 42,000           | 505              | 239                            | .90         | 29,100         | 65,600      | 21.4                  |
| 2B                           | 214,400        | 35,000           | 519              | 289                            | .90         | 29,100         | 65,600      | 21.4                  |
| 3B                           | 214,400        | 30,500           | 528              | 320                            | .90         | 29,100         | 65,600      | 21.4                  |
| 4B                           | 214,400        | 23,500           | 544              | 374                            | .90         | 29,100         | 65,600      | 21.4                  |
| 5B                           | 214,400        | 18,000           | 495              | 374                            | .80         | 29,100         | 65,600      | 21.4                  |
| 6B                           | 214,400        | 15,000           | 473              | 375                            | .75         | 29,100         | 65,600      | 21.4                  |

- DESIGN ENVELOPE CONDITIONS (14-32)
- LIGHT PROFILE CONDITIONS (1-13)
- PARAMETRIC VARIATIONS
- ◻ VERTICAL
- ◊ LATERAL

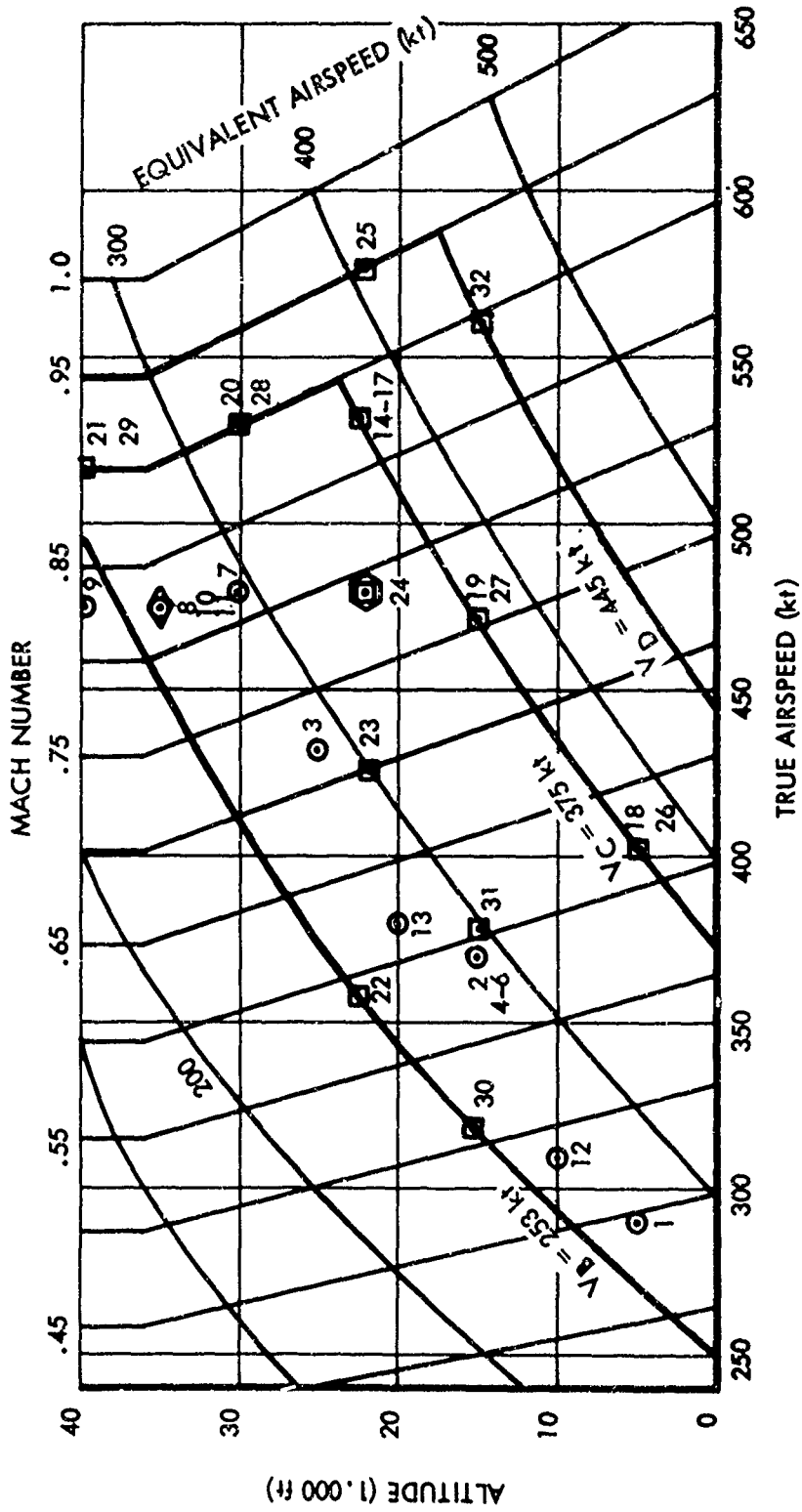


FIGURE 12. SPEED - ALTITUDE DIAGRAM

TABLE 5  
PARAMETRIC VARIATION CONDITIONS

| Gross Weight, Lb.                                    | Altitude Ft. | True Airspeed, Kt.                                                                                       | Equivalent Airspeed, Kt. | Mach No. | Payload, Lb. | Fuel Lb. | cg, Percent MAC |
|------------------------------------------------------|--------------|----------------------------------------------------------------------------------------------------------|--------------------------|----------|--------------|----------|-----------------|
| Vertical Analyses - Design Envelope Condition No. 24 |              |                                                                                                          |                          |          |              |          |                 |
| 186,000                                              | 22,000       | 480                                                                                                      | 340                      | .78      | 36,300       | 30,000   | 16.3            |
| Variation                                            |              |                                                                                                          |                          |          |              |          |                 |
|                                                      | 24A          | 80 Percent of Nominal Bending Stiffness                                                                  |                          |          |              |          |                 |
|                                                      | 24B          | 80 Percent of Nominal Torsional Stiffness                                                                |                          |          |              |          |                 |
|                                                      | 24C          | Most Aft cg Location, Changed from 16.3 to 25.0                                                          |                          |          |              |          |                 |
|                                                      | 24D          | No Structural Damping                                                                                    |                          |          |              |          |                 |
|                                                      | 24E          | No Gradual Penetration of Gust Front, Instantaneous Penetration                                          |                          |          |              |          |                 |
| Lateral Analyses - Flight Profile Condition No. 10   |              |                                                                                                          |                          |          |              |          |                 |
| 204,200                                              | 35,000       | 475                                                                                                      | 263                      | .82      | 29,100       | 55,400   | 21.5            |
| Variation                                            |              |                                                                                                          |                          |          |              |          |                 |
|                                                      | 10A          | Airplane Product of Inertia Changed from Nominal $7.75(10)^5$ to $-7.75(10)^5$ in. lb. sec. <sup>2</sup> |                          |          |              |          |                 |
|                                                      | 10B          | Airplane Product of Inertia, Twice Nominal Value                                                         |                          |          |              |          |                 |
|                                                      | 10C          | Airplane Product of Inertia, 1.5 times Nominal Value                                                     |                          |          |              |          |                 |
|                                                      | 10D          | Yawing Moment Due to Roll Rate Derivative, $C_{n_b \dot{\phi}}$ , Changed from Nominal .0065 to -.013.   |                          |          |              |          |                 |
|                                                      | 10E          | Yawing Moment Due to Roll Rate Derivative -.0189                                                         |                          |          |              |          |                 |
|                                                      | 10F          | Yawing Moment Due to Roll Rate Derivative -.0378                                                         |                          |          |              |          |                 |
|                                                      | 10G          | Yawing Moment Due to Yaw Rate Derivative, $C_{n_b \dot{\psi}}$ , Changed from Nominal -.180 to -.144     |                          |          |              |          |                 |
|                                                      | 10H          | Yaw Moment Due to Roll Rate Derivative, -.126.                                                           |                          |          |              |          |                 |



## ANALYSIS

### General Remarks

The Boeing Model 720B airplane was used to idealize the basic mathematical models for all analyses. Fig. 1 shows the airplane in flight. This airplane requires a crew of three, pilot, copilot and flight engineer, and has a maximum range of 3,300 miles. The airplane normally cruises from 15,000 to 40,000 ft. at gross weights in excess of 200,000 lb. and at speeds up to 615 miles per hour. The airplane has a wing span of approximately 131 ft., and an overall length of approximately 137 ft. A more detailed 3-view diagram of the airplane is shown in Fig. 13.

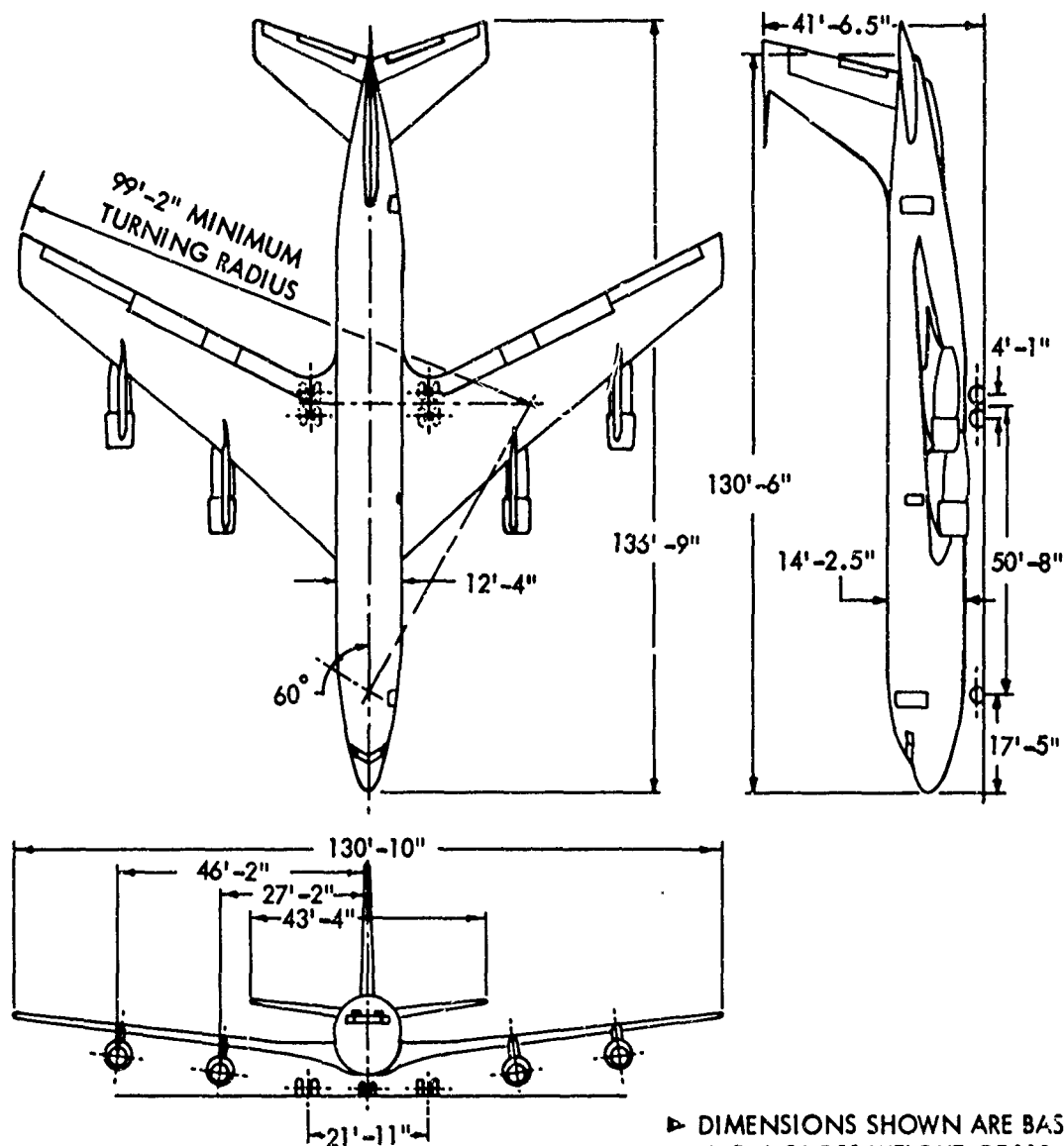
All major parts of the airplane except the horizontal stabilizer were considered to be elastic in the analyses. Therefore, a rather comprehensive mass and stiffness description of the airplane was required. Simple beam bending theory was used to represent the stiffness characteristics of the major components such as the wing, forward and aft fuselage, and the vertical tail. The elastic axes were generally located on the locus of shear centers along each component, but were adjusted to agree with information obtained in previous airplane static testing.

Structural damping for the various airplane flexible modes of vibration was taken directly from whole airplane shake test results<sup>(17)</sup>.

Considerable airplane test data was available to formulate the mathematical models that were used in the analyses of the 720B. The method used to represent the detailed aerodynamics, mass, and stiffness characteristics are not complex, but they do provide a solid basis for understanding the airplane's dynamic response characteristics. The airplane responses obtained herein by analysis show good agreement with static aeroelastic results for slow maneuvers and with flutter analyses for the higher frequency elastic responses.

### Airplane Mass Data

The weight and inertia data for the analyses were originally calculated from released detailed drawings and have been updated as drawing changes or actual weights became available. The airplane fuselage was divided into eighteen panels and the mass properties in the form of weight, center of gravity, and mass moments of inertia for pitch, roll and yaw were determined for each section. Mass data for the operating weight empty (OWE) configuration and for full and partial payloads were calculated to facilitate selection of partial payload conditions.



► DIMENSIONS SHOWN ARE BASED UPON GROSS WEIGHT OF 110,000 POUNDS AND CENTER OF GRAVITY AT 15% OF MAC

FIGURE 13. 3 - VIEW DIAGRAM OF 720B

The wing structure and contents with the exception of fuel were divided into ten spanwise panels. Each of these panels was further divided into five zones: the leading edge, front spar, inner spar, rear spar and trailing edge. The weight and center of gravity were calculated for each zone and summed to give the total panel weight and center of gravity. The total panel mass moments of inertia were computed by rotation and transfer of zone results into axes parallel and perpendicular to the wing elastic axis.

The vertical tail structure and contents were divided into seven spanwise panels and the section mass properties were calculated in the same manner as the wing. The horizontal stabilizer was considered as a single panel for these analyses. The lumped mass properties for the horizontal stabilizer were obtained by combining previously panelled data which were obtained in the same manner as the wing and vertical tail data.

The mass properties for each JT3D-1 engine, nacelle, and nacelle strut were combined, and a lumped center of gravity location determined. Then, the nacelle mass moments of inertia were determined for axes perpendicular and parallel to the airplane reference axes.

The fuel mass properties were obtained for conditions representing fuel loadings of 25, 50, 75 and 100 percent of full fuel. The particular percentage used was determined by the flight condition being analyzed. Fuel weights and cg positions were calculated by a computer program which accounted for the geometry of each tank.

The accuracy of the mass properties used in these analyses is estimated to be within 1.0 percent for the total airplane weight, 2.0 in. for total airplane center of gravity location, and 3.0 percent for the total airplane mass moments of inertia. Also, it is estimated that the panelled mass data and the major airplane component mass data are accurate to similar limit.

#### Component Stiffnesses

The stiffness characteristics of each major component of the airplane was described by a distribution of bending stiffness, EI, and torsional stiffness, GJ, along the elastic axis. The wing section properties were computed using front and rear spar areas and all inspar skin for both the upper and lower surfaces. Values for the modulus and shear modulus of elasticity, E and G, were  $10.3(10)^6$  and  $3.8(10)^6$  psi, respectively. The body section properties were computed using stiffeners with full skin effective in tension and 2W widths of skin effective in compression. The body cutout sections were handled on an individual basis by special analysis.

The section properties for determining the bending stiffness of the vertical tail were computed using front and rear spar chord area with 2W widths of skin assumed effective on the compression side of the rear spar chord in trailing edge beam areas. Fully effective tension skin was assumed between the front and rear spars and for balance panel covers. Near the body intersection, the inspar skin and front spar areas are assumed to be partially effective because of shear lag. The section properties for the determination of the torsional stiffness of the vertical tail were computed using front and rear spar areas and all inspar skin for both surfaces.

#### Aerodynamics - Vertical Analyses

The stresses induced into the airplane structure for unaccelerated flight in turbulent air result from the sum of the one factor aerodynamic and inertia forces on the airplane, the gust forces, and the dynamic response forces. The one factor flight loads and stresses were added to the respective incremental dynamic loads and stresses to assess the strength capabilities of the 720B airplane for flight in turbulent air.

The one factor level flight loads, that is bending moments, shears, and torsions, were determined by aeroelastic analyses.<sup>(6,7)</sup> All of the basic aerodynamic data required for these analyses were obtained from a series of wind tunnel tests performed for the entire Mach number range. Wind tunnel pressure model test results were used to establish wing, fuselage, and vertical tail airload distributions. The section lift and moment coefficients were corrected for model flexibility before they were used for full scale airplane analysis, and were later refined to obtain final agreement between the aeroelastic analyses and actual airplane flight load survey measurements.

The rigid airplane aerodynamic section coefficients, corrected to provide agreement with flight measurements, can be used to obtain an aeroelastic solution for any longitudinal maneuvered flight condition. Simultaneous equations are solved to obtain an aeroelastic solution. These equations define the following: (1) wing lift distribution on 10 aerodynamic sections on the wing semi-span, (2) airplane lift balance, and (3) the airplane pitching moment balance. Specifically, the solution gives the elastic wing lift distribution, the airplane wing root angle of attack, and the balancing tail load.

The unsteady aerodynamics used in the vertical dynamic analyses are based on modified two-dimensional strip theory.<sup>(8)</sup> The strip theory, originally developed by Theodorsen<sup>(9)</sup> and Küssner,<sup>(10)</sup> has been modified to include aerodynamic induction effects<sup>(3)</sup>. These induction effects

account for the aerodynamic pressure carry-over between wing panels and between the wing and horizontal tail. This is accomplished by using a downwash matrix based on lifting line theory. The dynamic downwash matrix includes pressure carry-over and pressure transmittal functions to provide the proper magnitude and phasing of the carry-over pressures. The section (strip) aerodynamics for zero frequency are made to agree with the comparable aeroelastic solution. The results of this modification have been compared to experimental results and to theoretical results based on lifting surface theories; satisfactory correlation was obtained. (8)

The unsteady aerodynamic expressions for the vertical analyses were calculated for a range of reduced frequencies to adequately define the airplane dynamic responses. The gust or excitation airforces for a sinusoidal gust field were also expressed in a modified two-dimensional form for the same reduced frequency values. The aerodynamic forces acting on the fuselage were obtained using simple quasi-steady aerodynamic expressions. The fuselage was first divided into thirteen streamwise panels, seven on the forebody and six on the aftbody. A static pressure distribution was then used to determine the individual panel lift and moment coefficients. The panel angles of attack were assumed to arise from the deflection slopes and displacement velocities of the fuselage.

#### Aerodynamics - Lateral Analyses

The lateral dynamic response of large swept wing subsonic jet transports is generally dominated by the low damped Dutch roll mode. The damping of this mode, as determined by dynamic analysis, is very sensitive to the estimated rotary stability derivatives used in the equations of motion. Large changes in the lateral gust loads result from small changes in particular rotary derivatives for flight conditions in which the Dutch roll damping is low.

All of the airforces and inertia forces were referenced to the airplane stability axes. The stability axes were determined as the orthogonal set attached to the airplane with the initial orientation of the x-axis in the wind direction for undisturbed and unaccelerated flight. The airplane angle of attack for one factor level flight was determined by a separate aeroelastic analysis for each condition.

The lateral stability derivatives were decomposed into wing, fuselage, and vertical tail components. The pressure distributions for the fuselage and the vertical tail were determined from wind tunnel pressure model test data. The aerodynamic side force and moment from the wing were accounted for by a concentrated side force and a moment applied to

the airplane center of gravity. The integrated force and moment resulting from the aerodynamic pressures on the fuselage and vertical tail together with the concentrated force and moment from the wing were made to agree with the lateral whole airplane derivatives.

#### Generalized Coordinates

Each dynamic analysis was conducted for a mathematical model which was in equilibrium at one factor level flight. When such a system is subjected to an external sinusoidal gust field, it responds about its static equilibrium configuration. This gives rise to displacements, velocities and accelerations necessary to preserve the energy balance with the external gust loading. The structural deformation of the airplane can be described as a sum of incremental displacements in the system's natural modes of vibration. These deflected shapes and whole airplane rigid body displacements are used as the so-called generalized coordinates to describe the airplane motions. The development of the equations of motion by the Lagrangian approach using these generalized coordinates is discussed in Appendix A.

The natural modes of vibration of a flexible system can take various forms depending upon the manner in which the system is restrained. When the airplane is in flight there are no external restraints, and the airplane can displace with complete freedom. There are several methods by which this so-called free-free state can be described. One method is to define the cantilevered vibration modes of each major component, such as the wing, body, and nacelles by separate orthogonal mode sets. A limited number of these cantilevered modes along with the rigid airplane freedoms are used as the generalized coordinates to describe the overall airplane response.

A better set of generalized coordinates is obtained when a large number of cantilevered modes are coupled with the rigid airplane freedoms to produce a set of unrestrained free-free airplane normal modes. The advantages of this approach is that the overall airplane response can be more accurately described by fewer degrees of freedom or generalized coordinates than in the cantilevered mode approach. The free-free normal mode approach was used for the 720B vertical analyses, and the cantilevered mode approach was used for the lateral analyses. A representative summary of cantilevered modes which were coupled with airplane vertical translation and pitch freedoms for the vertical analyses is given in Table 6. Corresponding representative airplane free-free modal data is given in Table 7. A summary of cantilevered modes used in the lateral analyses is given in Table 8.

TABLE 6  
REPRESENTATIVE CANTILEVERED MODES  
VERTICAL ANALYSES

| Airplane<br>Component | No. of<br>Discrete<br>Masses** | Cantilevered<br>Mode<br>Description | Modal Frequency, cps |              |              |
|-----------------------|--------------------------------|-------------------------------------|----------------------|--------------|--------------|
|                       |                                |                                     | OWE                  | Half<br>Fuel | Full<br>Fuel |
| Wing                  | 10                             | 1st Bending                         | 1.31                 | 1.27         | .93          |
|                       |                                | 2nd Bending                         | 3.77                 | 3.51         | 2.81         |
|                       |                                | 3rd Bending                         | 7.75                 | 6.59         | 5.83         |
|                       |                                | 4th Bending                         | 10.67                | 10.62        | 9.28         |
|                       |                                | 1st Torsion                         | 2.52                 | 2.52         | 2.52         |
|                       |                                | 2nd Torsion                         | 5.19                 | 5.18         | 5.19         |
|                       |                                | 3rd Torsion                         | 19.79                | 19.28        | 18.42        |
| Forward<br>Fuselage   | 7                              | 1st Bending                         | 3.99                 | 3.71         | 3.71         |
| Aft<br>Fuselage       | 13*                            | 1st Bending                         | 2.57                 | 2.46         | 2.46         |
|                       |                                | 2nd Bending                         | 9.87                 | 8.62         | 8.62         |
| Inboard<br>Nacelle    | 1                              | Vertical Bending                    | 4.31                 | 4.31         | 4.31         |
|                       |                                | Coupled Side<br>Bending & Torsion   | 2.07                 | 2.07         | 2.07         |
| Outboard<br>Nacelle   | 1                              | Vertical Bending                    | 4.28                 | 4.28         | 4.28         |
|                       |                                | Coupled Side<br>Bending & Torsion   | 2.24                 | 2.24         | 2.24         |

\*Includes horizontal and vertical tail masses.

\*\*See Fig. 23

TABLE 7  
REPRESENTATIVE FREE-FREE NORMAL MODES  
VERTICAL ANALYSES

| Mode No. | Responding Component | Modal Frequency, cps |           |           |                        | Structural Damping, g** |
|----------|----------------------|----------------------|-----------|-----------|------------------------|-------------------------|
|          |                      | OWE                  | Half Fuel | Full Fuel | Ground Vibration Test* |                         |
| 1        | Wing Bending         | 1.40                 | 1.35      | 1.08      | 1.44                   | .040                    |
| 2        | Nacelle              | 2.07                 | 2.07      | 2.05      | 2.07                   | .027                    |
| 3        | Nacelle              | 2.22                 | 2.20      | 2.14      | --                     | .037                    |
| 4        | Wing Torsion         | 2.46                 | 2.44      | 2.25      | 2.96                   | .022                    |
| 5        | Forward Fuselage     | 3.32                 | 3.26      | 3.19      | 3.75                   | .030                    |
| 6        | Fuselage             | 4.07                 | 3.65      | 3.40      | 5.40                   | .030                    |
| 7        | Wing Bending         | 6.07                 | 5.30      | 4.55      | 6.50                   | .030                    |

\*The ground vibration test was conducted for the 720 airplane with the main gear and nose gear restrained. (Ref. 17)

\*\*Damping coefficient, g, is equal to twice the actual damping divided by the critical damping.



TABLE 8  
CANTILEVERED MODES LATERAL ANALYSES

| Airplane Component | No. of Discrete Masses* | Cantilevered Mode Description | Modal Frequency, cps |
|--------------------|-------------------------|-------------------------------|----------------------|
| Aft Fuselage       | 12                      | 1st Side Bending              | 2.41                 |
| Aft Fuselage       | 12                      | 2nd Side Bending              | 7.22                 |
| Aft Fuselage       | 12                      | 1st Torsion                   | 5.83                 |
| Forward Fuselage   | 7                       | 1st Side Bending              | 3.66                 |
| Fin                | 13                      | 1st Bending                   | 4.34                 |
| Fin                | 13                      | 1st Torsion                   | 14.62                |

\*See Fig. 24

### Equations of Motion

The equations of motion for the 720B gust analyses were developed by Lagrange's energy approach. The derivation of vertical and lateral equations of motion is discussed in Appendix A. The equations for both analyses are a set of simultaneous second-order differential equation in the generalized coordinates described previously. These equations can be expressed in matrix form as follows:

$$[M_{ij}] \{\ddot{q}_i\} + [D_{ij}] \{\dot{q}_i\} + [K_{ij}] \{q_i\} = \{C_i\} a_g \quad (4)$$

The coefficient matrices of  $\ddot{q}_i$ ,  $\dot{q}_i$ , and  $q_i$  are the generalized mass,  $[M_{ij}]$ , the structural and aerodynamic damping,  $[D_{ij}]$ , and the structural and aerodynamic stiffness,  $[K_{ij}]$ , respectively. The right hand side of the equation represents the generalized forces in the degrees of freedom due to the gust excitation,  $\{C_i\}$ .

The generation of the generalized mass coefficient matrix began with the lumped mass representation of the airplane in terms of discrete masses and mass moments of inertia about the discrete mass center of gravity for each mass panel. Then, the center of gravity mass properties were transferred to their respective elastic axis reference stations. The total kinetic energy of the system was written in terms of generalized coordinate velocities. Differentiation of the kinetic energy expression, first with respect to the generalized coordinate velocities, and then with respect to time, resulted in the generalized mass matrix,  $[M_{ij}]$ .

The damping coefficients arise partly from the aerodynamic response forces and partly from structural damping. The aerodynamic damping results from that portion of the total aerodynamic force which is in phase with the particular generalized coordinate velocities. The structural damping is represented as forces that are proportional to the structural stiffnesses but are in phase with the response velocities. The values for structural damping used in the vertical analyses were obtained from ground vibration tests of the 720 airplane. The damping coefficient for each mode for the vertical analyses is listed in Table 7. The energy or work expression for these damping forces was differentiated with respect to each coordinate to arrive at the generalized damping matrix,  $[D_{ij}]$ .

The stiffness matrix also results from structural and aerodynamic sources. The stiffness of the primary airplane structure is represented in the equations of motion by the elastic potential energy stored in the structure when it is deformed in a linear combination of the selected vibration mode shapes. The aerodynamic work resulting from the response

displacements of the primary components of the airplane is added to the internal elastic energy and the entire expression is differentiated with respect to each generalized coordinate to form the stiffness matrix,  $[K_{ij}]$ .

The yaw damper effects in the lateral equations of motion are handled by including a generalized force specifically for the yaw damper. This generalized force is a function of both the gust excitation frequency and the resulting airplane yawing velocity. The yaw damper system consists of a yaw rate sensor, a yaw axis amplifier, a servo system with rudder position and rudder angular rate feedback loops, and an hydraulic rudder actuator unit.

In the airplane, the signal from the yaw rate sensor is filtered to remove the effects of both slow maneuvers and higher frequency fuselage vibrations. The filtered signal is amplified and applied to an electronic servo which, in turn, drives the hydraulic rudder actuator.

The yaw damper system is simulated in the lateral analyses by incorporating a transfer function due to yawing velocity. This transfer function is a composite of the transfer functions for all of the sub-parts of the yaw damper system. The generalized force associated with the rudder deflection varies with frequency, but it is a function of yaw rate only at any given frequency. The generalized force coefficients were added to the coefficients in the rudder-fixed equations of motion to account for the yaw damper effects. A more complete description of the mathematical model for the yaw damper is given in Appendix A, Equations of Motion.

Both the vertical and lateral equations of motion were solved to obtain the real and imaginary parts of the steady-state complex responses of the generalized coordinates due to a 1.0 ft. per sec. continuous sinusoidal gust velocity excitation. Consequently, the accelerations,  $\ddot{q}_i$ , could be replaced by  $-\omega^2 q_i$  and the velocity,  $\dot{q}_i$ , by  $i\omega q_i$ , where  $\omega$  is the excitation frequency. When these assumptions were incorporated into the equations of motion, the matrix coefficients  $\omega^2[M_{ij}]$ ,  $i\omega[D_{ij}]$  and  $[K_{ij}]$  could be combined into a single complex set of matrix coefficients  $[A_{ij} + iB_{ij}]$  of the generalized coordinates for each frequency. The generalized coordinate responses were obtained by premultiplying the generalized gust forces,  $\{C_i\}$ , by the inverse of this matrix for each of the selected frequencies.

Solutions were obtained in the vertical analyses to define the complex frequency response functions over the range from  $0.5(10)^{-5}$  to 0.6 rad. per ft. The sensitivity of the rms values,  $\bar{A}$ , and the number of zero crossings,  $N_0$ , to the upper and lower limits of the frequency range and to the overall number of frequencies was examined. The lower end of the

frequency range was taken at  $0.5(10)^{-5}$  rad. per ft which was well below the short period mode response frequency. The maximum frequency, 0.6 rad. per ft., was sufficiently high such that the number of zero crossings had converged. A total of 95 frequencies between the above limits were used in the vertical analysis. The major contribution to the rms values is in the lower end of the frequency range; therefore, the solution frequencies were selected at closer intervals in the lower frequency range.

#### Load Equations

The detailed loads for the aircraft structure were obtained from the complex frequency responses of the generalized coordinates. This was accomplished by transforming the generalized inertia, damping and stiffness forces used in the equations of motion into shears, bending moments, and torsions referenced to given stations on the elastic axes. The shear, moment, and torsion coefficients were calculated for unit deflections in the generalized coordinates. Then, these coefficients were multiplied by the complex frequency responses of the generalized coordinates to obtain load complex frequency responses for all elastic axis reference stations.

Complex frequency response functions for stresses were obtained by incorporating unit load solution stress coefficients from the airplane stress analyses(11,12,13) into the load equations.

#### Spectral Analysis

The complex frequency response functions for the incremental shears, moments, and torsions were used to define complex frequency response functions for incremental axial and shear stresses in the detailed airplane structure. The output power spectra for the loads and stresses were obtained as follows:

$$\phi_o(\Omega) = \phi_w(\Omega) |T(i\Omega)|^2 \quad (5)$$

where,

- $\phi_o(\Omega)$       output, load or stress power spectral density function
- $\phi_w(\Omega)$       input, normalized vertical or lateral gust power spectral density function
- $T(i\Omega)$       complex frequency response function for load or stress at a given station in the airplane

The rms values for the loads and stresses for a rms gust velocity of unity,  $\bar{A}$ , were determined by integrating the appropriate output power spectrum.

$$\bar{A} = \left[ \int_0^{\infty} \phi_o(\Omega) d\Omega \right]^{1/2} \quad (6)$$

The zero crossings per ft. for all loads and stresses were determined by Rice's expression<sup>(14)</sup>.

$$N_o = \frac{1}{2\pi} \left[ \frac{\int_0^{\infty} \Omega^2 \phi_o(\Omega) d\Omega}{\int_0^{\infty} \phi_o(\Omega) d\Omega} \right]^{1/2} \quad (7)$$

Since the actual strength of a detailed structural element is in general governed by the combined stresses, stress interaction functions and one factor level flight stresses must be incorporated into the statistical analysis. The problem was to determine the probability of exceeding the limit strength for a given flight condition (Design Envelope Approach) and to determine the number of times the limit strength is exceeded per unit time (Flight Profile Approach). The joint probability density function for two components of stress on a structural element, say, axial stress and shear stress is,

$$P(f, \xi) = \frac{1}{2\pi} \frac{1}{\sigma_f \sigma_{\xi} (1-\rho^2)^{1/2}} \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{(f-f_o)^2}{\sigma_f^2} - \frac{2\rho(f-f_o)(\xi-\xi_o)}{\sigma_f \sigma_{\xi}} + \frac{(\xi-\xi_o)^2}{\sigma_{\xi}^2} \right] \right\} \quad (8)$$

where,

f        axial stress, psi  
 ξ        shear stress, psi

$f_o, \xi_o$     one factor axial and shear stresses, respectively, psi  
 $\sigma_f, \sigma_\xi$     rms axial and shear stresses, respectively, psi  
 $\rho$             correlation coefficient

#### Statistical Analysis - Design Envelope Approach

The volume under the probability density functions shown in Fig. 14 bounded by the interaction limit strength envelope is equal to the probability that the limit strength will not be exceeded, that is, that the margin of safety is greater than zero. The probability that the limit strength will be exceeded is 1.0 minus the probability that the limit strength will not be exceeded. Therefore,

$$P(MS < 0) = 1 - P(MS \geq 0) \quad (9)$$

Since the input or gust power spectral density varies directly with the mean squared gust velocity,  $\sigma_w^2$  or  $\sigma_v^2$ , the probability of exceeding the limit design strength is a function of  $\sigma_w$  or  $\sigma_v$ . That is,

$$\sigma_f = \bar{A}_f \sigma_w \quad (10)$$

and

$$\sigma_\xi = \bar{A}_\xi \sigma_w \quad (11)$$

Consider a stiffened skin-stringer segment typical of those used in wing panel construction of subsonic jet transport airplanes. A cross section through the segment normal to the stringer is shown in Fig. 15. It was assumed that the airplane, of which this structural element is a part, was flying in turbulent air. It was of interest to determine (1) the probability of exceeding the limit design strength of the segment and (2) the expected number of times per hour that the limit strength would be exceeded for various root mean square (rms) gust velocities,  $\sigma_w$ .

Numerical information pertinent to this example is given in Table 9. The appropriate limit strength interaction diagram is shown with a sketch of the structural segment in Fig. 15. It will be noted that two level-flight stress points, skin stress and segment stress, are shown in

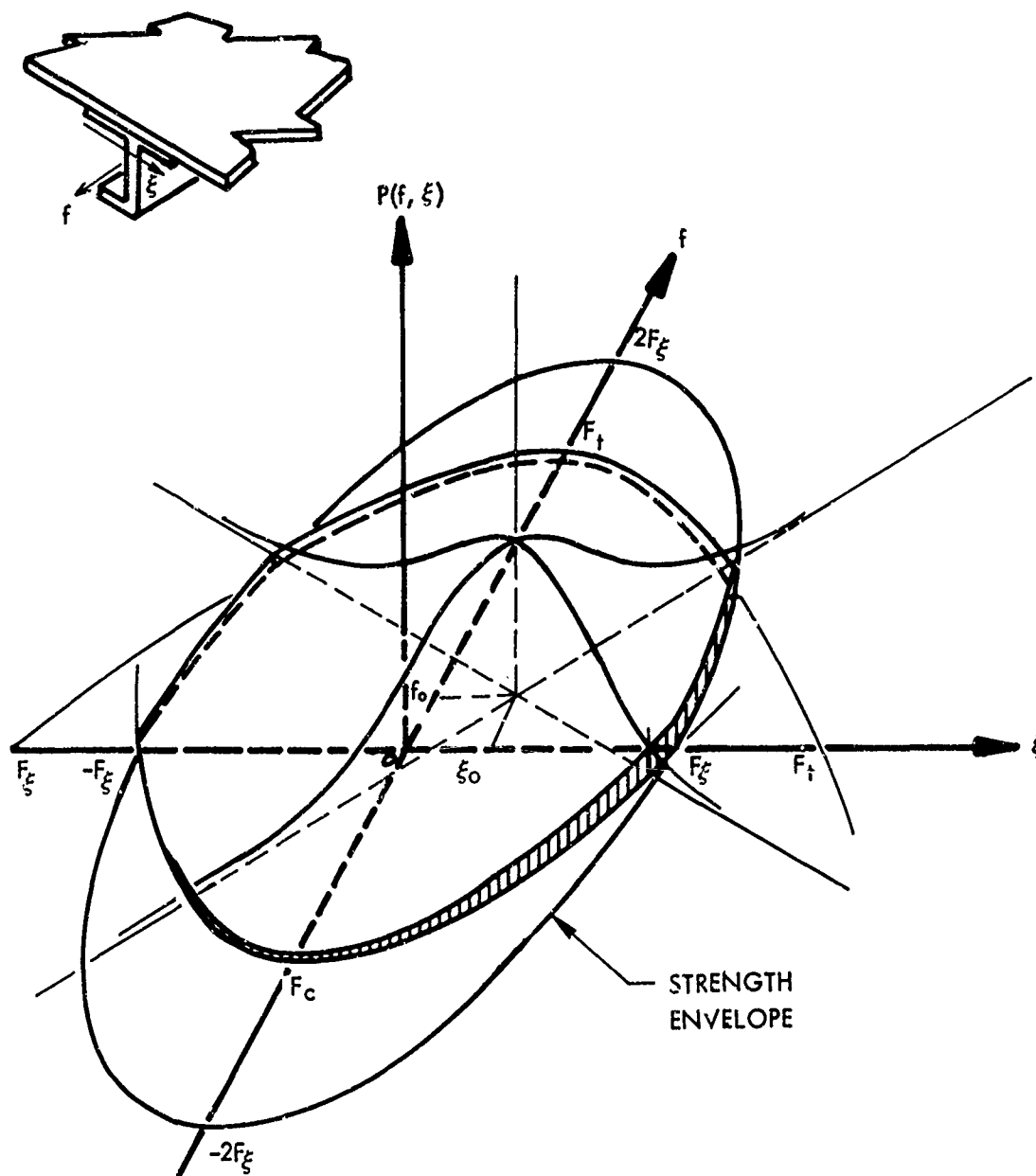


FIGURE 14. JOINT GAUSSIAN PROBABILITY DENSITY FUNCTION

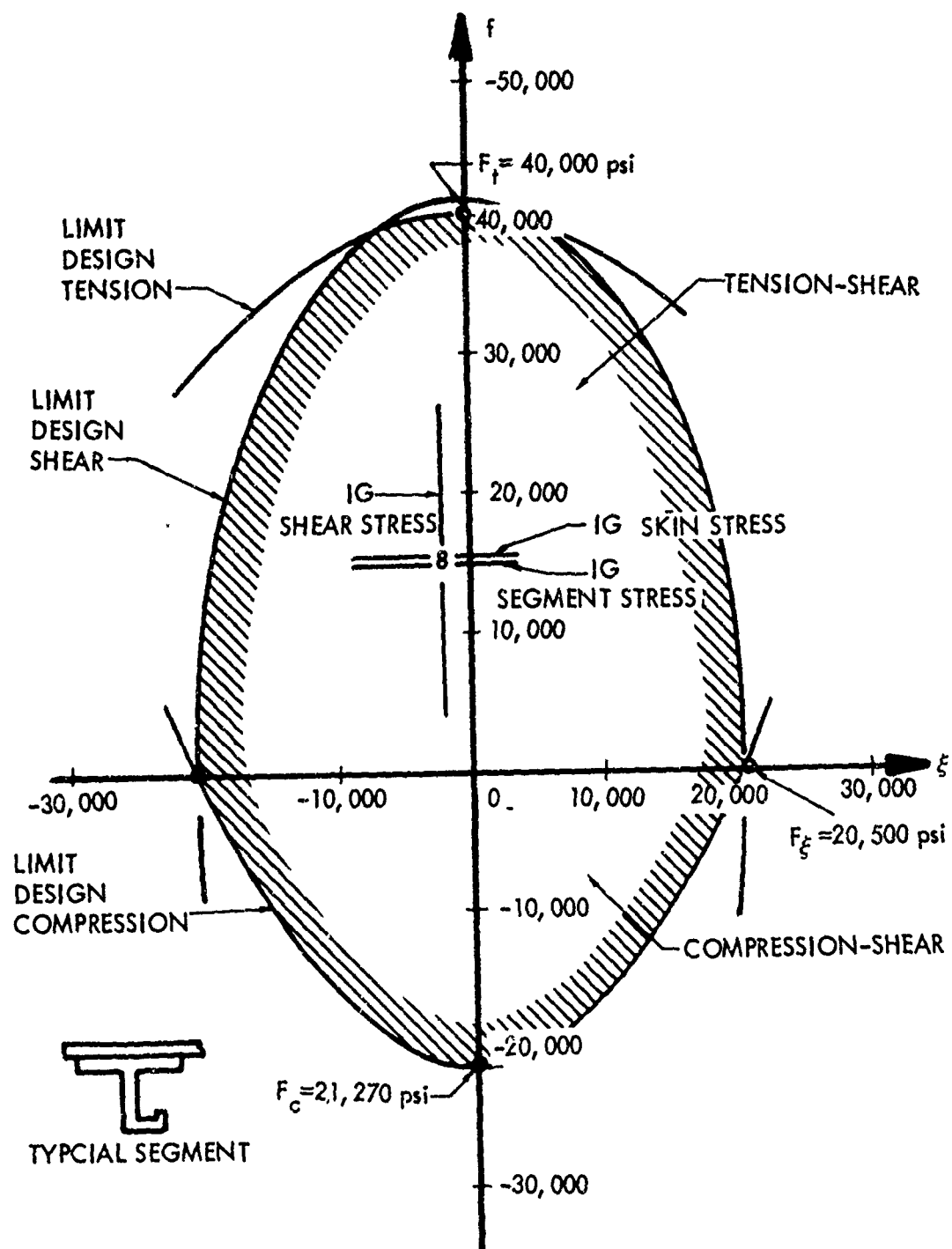


FIGURE 15. TYPICAL SKIN-STRINGER SEGMENT AND STRENGTH INTERACTION DIAGRAM



TABLE 9  
NUMERICAL EXAMPLE  
STRESS DATA FOR STATISTICAL ANALYSIS\*

Level Flight Stresses (Based on Appropriate Effective Areas)

|                                             |        |
|---------------------------------------------|--------|
| Skin Stress, Tension $f_{ot}$ , psi         | 15,600 |
| Segment Stress, Compression, $f_{oc}$ , psi | 15,200 |
| Shear, $\xi_o$ , psi                        | -2,190 |

Dynamic Analysis Stress Data (Power Spectral Analysis-RMS Gust Velocity,  
 $\sigma_w = 1.0$  ft. per sec.)

|                                                       |         |
|-------------------------------------------------------|---------|
| RMS Tension Stress, $\bar{A}_{ft}$ , psi              | 184.19  |
| RMS Compressive Stress, $\bar{A}_{fc}$ , psi          | 179.51  |
| RMS Shear Stress, $\bar{A}_{\xi}$ , psi               | 38.53   |
| Correlation Coefficient<br>(Axial and Shear Stresses) | -0.2141 |
| Zero Crossings per sec                                |         |
| Axial Stress, $N_{of}$                                | 1.2205  |
| Shear Stress, $N_{o\xi}$                              | 2.7235  |
| RMS Stress Rates, psi per ft. per sec                 |         |
| Tension, $\sigma_{\beta_t}$                           | 1,413   |
| Compression, $\sigma_{\beta_c}$                       | 1,377   |
| Shear, $\sigma_{\alpha}$                              | 659     |

Allowable Limit Design Stresses, psi

|                    |        |
|--------------------|--------|
| Tension, $F_t$     | 40,000 |
| Compression, $F_c$ | 21,270 |
| Shear, $F_{\xi}$   | 20,500 |

\*See Appendix B for development of methods for Statistical Analysis  
of Combined Random Stresses

Table 9 and in Fig. 15. These are reference points for two joint probability stress distributions. The compression-shear or segment stress probability distribution was applied to the compression portion of the interaction diagram in Fig. 15, and the tension-shear or skin stress distribution was applied to the tension portion of the diagram. The volume of the compression-shear joint probability density function within the compression region of the interaction diagram was added to the volume of the tension-shear density function in the tension region to determine the probability that the limit design strength will not be exceeded. A typical plot of  $P(MS < 0, \sigma_w)$  versus  $\sigma_w$  is shown in Fig. 16.

Certain structural elements in the fuselage near either the vertical or lateral bending axis are only subjected to fluctuating compression stresses and shear. They cannot be stressed in tension as a result of the gust loading. This occurs, because the location of the neutral plane through the fuselage section shifts across the element as the direction of the bending moment on the fuselage changes sign. The element is always on the compression side of the neutral plane. This compression-compression situation was handled in the statistical analysis of limit strength exceedances by removing the tension part of the interaction diagram and by substituting another compression part. Now, these special cases could be treated in the same manner as normal elements.

The objective of the design envelope approach was to determine a level of gust intensity,  $\sigma_w \eta_d$ , which when multiplied by a stress  $\bar{A}$  value for a critical element would just equal the limit design strength for the element. Thus, the design envelope approach implies a one-dimensional probability distribution for design stress. The statistical distribution of stress values is assumed to be Gaussian and can be completely described by the rms stress value for a one-dimensional distribution.

When the probability of exceeding limit strength is governed by a joint probability function in two dimensions, three parameters, i.e. two rms stress values and a correlation coefficient, are required. As a result, no single statistical parameter can be scaled-up to a design strength level. However, the probability of exceeding the design strength of the element can be matched to : probability for exceeding an incremental cg acceleration\* for the same flight condition. The distribution of

---

\*The development that follows is essentially unchanged if the c.g. acceleration is replaced by a generalized load quantity,  $y/\bar{A}$ . Thus it can be seen that the numerical results are not dependent upon the choice of the particular output quantity for which the single-parameter probability distribution is obtained.

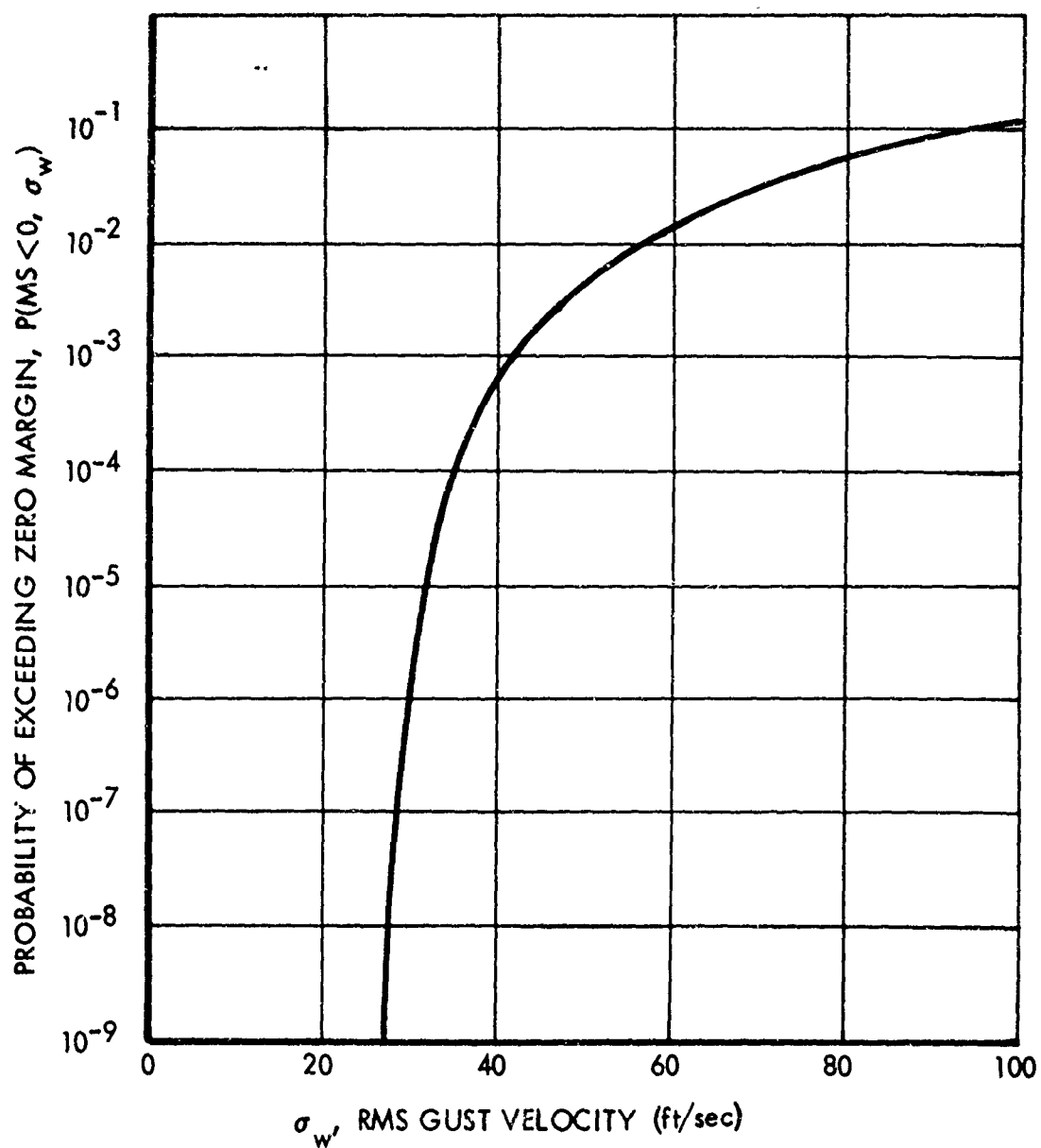


FIGURE 16. PROBABILITY OF EXCEEDING LIMIT DESIGN STRENGTH FOR VARIOUS RMS GUST VELOCITIES

incremental cg acceleration is a single parameter distribution, and a unique  $\sigma_w \eta_d$  can be determined for that level of incremental cg acceleration.

The probability of exceeding specified values of incremental cg acceleration is determined as follows:

$$P(\Delta n > \Delta n_i, \sigma_w) = \frac{2}{\sqrt{2\pi} \bar{\Delta} \sigma_w} \int_{\Delta n_i}^{\infty} e^{-\Delta n^2 / 2 \bar{\Delta}^2 \sigma_w^2} d\Delta n \quad (12)$$

This equation is evaluated for various specified  $\bar{\Delta} \sigma_w$  values to obtain the distribution functions shown in Fig. 17. It will be noted that the diagrams in Fig. 17 are universal, and can be applied to any airplane at any altitude.

Of course, the cumulative distribution functions shown in Figs. 16 and 17 will differ, because the first is based on joint probability considerations, and the second is a single parameter distribution. The two distribution functions cannot be made to coincide everywhere. The question was, where should they be matched?

When each probability function is multiplied by  $\hat{f}(\sigma_w)$ , the probability density of rms gust velocity, and integrated over all  $\sigma_w$ , we obtain a new probability number indicating the chance of exceeding the design strength at any instant in time for all weather and seasonal conditions. Typical overall probability density functions for incremental cg acceleration are shown in Fig. 18. Similar typical information for a structural element is shown in Fig. 19.

It is obvious that one curve of the family of curves shown in Fig. 18 will best match the curve in Fig. 19. The cg acceleration curve that best matches the curve for the structural element is the one having very nearly the same area when integrated. It is noted that the maxima of the overall probability density curves for cg acceleration lie on a straight line as shown in Fig. 18, and it is possible to cross plot the maximum overall probability density versus acceleration level as shown in Fig. 20. This diagram is unique for the flight condition. The straight line will intersect the vertical axis at  $\hat{f}(\sigma_w) = \hat{f}(0)$  since  $P(\Delta n > 0) = 1.0$ . Now it is possible to determine  $\sigma_w \eta_d$  for the structural element by determining the maximum probability density in Fig. 19, (9.0(10)<sup>-13</sup>). This maximum probability density was used in Fig. 20 to determine  $\Delta n_i$ , (1.39), and  $\sigma_w \eta_d$  for the element.

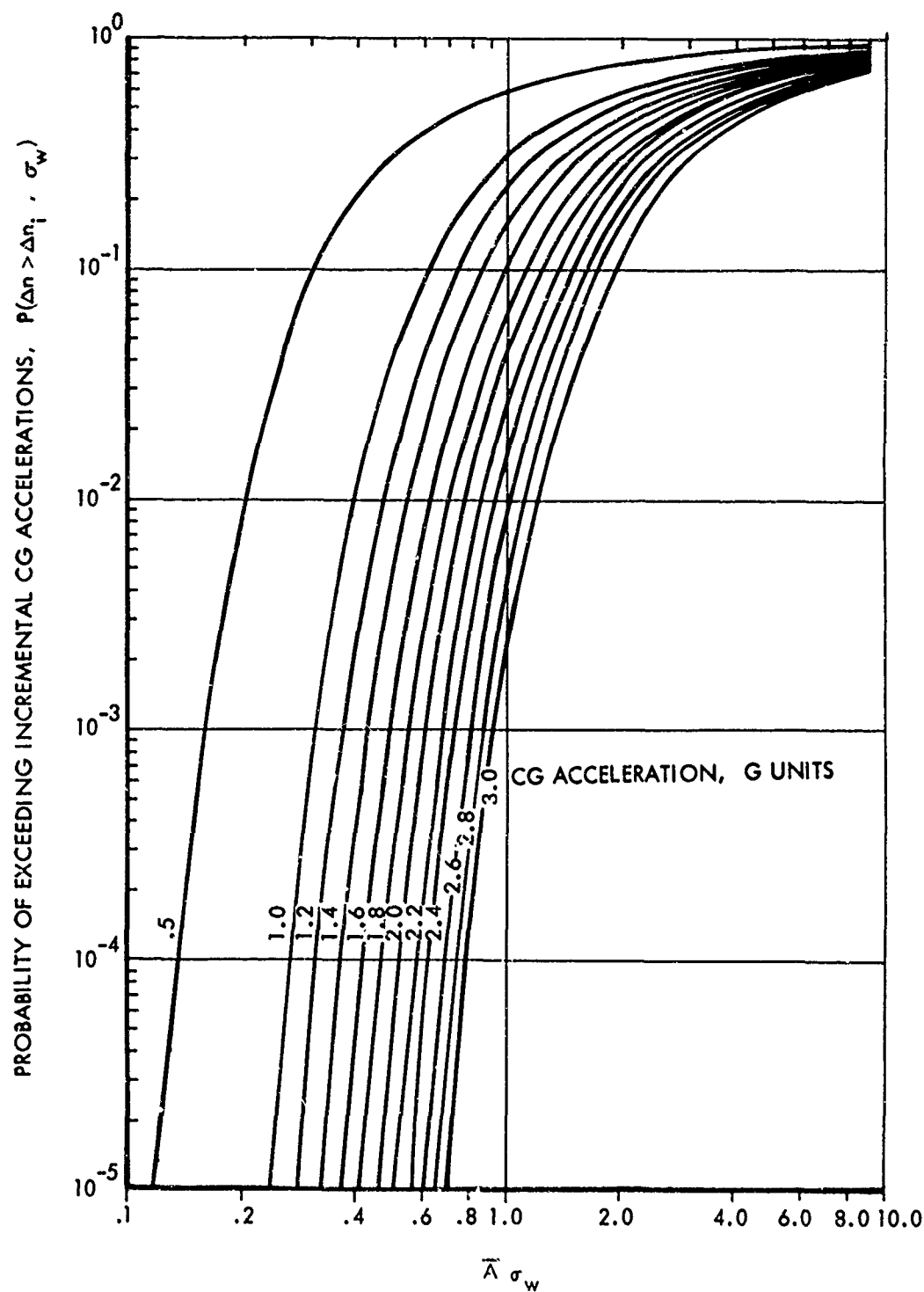


FIGURE 17. PROBABILITY OF EXCEEDING SPECIFIED INCREMENTAL CG ACCELERATIONS FOR VARIOUS RMS GUST VELOCITIES

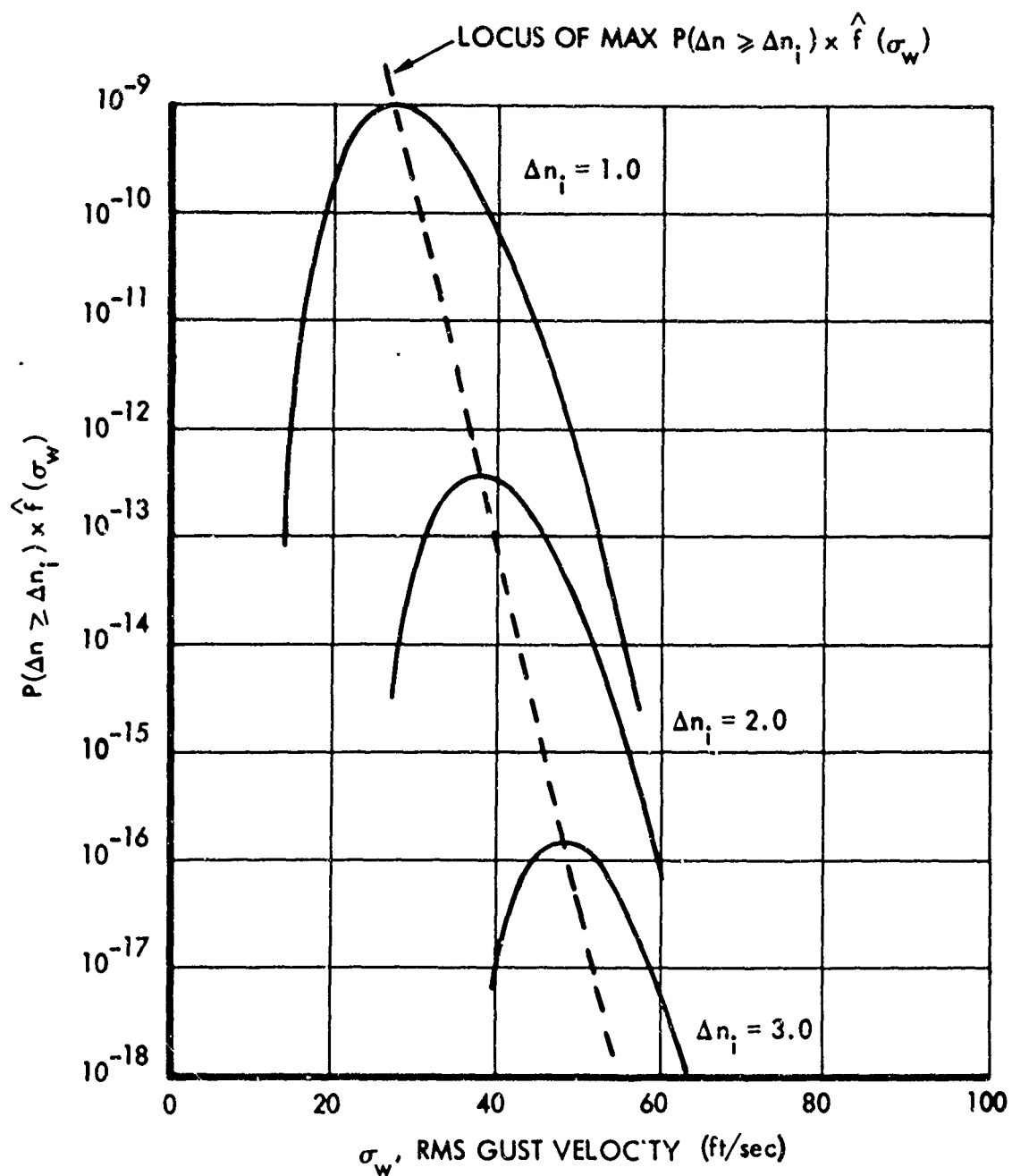


FIGURE 18. OVERALL PROBABILITY DENSITIES FOR EXCEEDING SPECIFIC INCREMENTAL CG ACCELERATIONS

$$\sigma_w \eta_d = \frac{\Delta n_1}{\sigma_{\Delta n}} = \frac{1.39}{.0138} = 137 \quad (13)$$

It is obvious that the limit design gust intensity,  $\sigma_w \eta_d$ , would vary with altitude, since the statistical characteristics of atmospheric turbulence changes with altitude. This variation is accounted for by use of Eq. (14).

$$N(y) = P_1 N_0 e^{-y/b_1 \bar{A}} + P_2 N_0 e^{-y/b_2 \bar{A}} \quad (14)$$

When we consider  $y/\bar{A}$  to be a limit design gust velocity,  $\sigma_w \eta_d$ ; then, Eq. (14) is rewritten as follows:

$$\frac{N(\sigma_w \eta_d)}{N_0} = P_1 e^{-(\sigma_w \eta_d)/b_1} + P_2 e^{-(\sigma_w \eta_d)/b_2} \quad (15)$$

( $\bar{A} = 1.0$ )

The value,  $N(\sigma_w \eta_d)/N_0$ , is thought of as an exceedance ratio. It is the ratio of the number of gusts exceeding the limit design gust per unit time or distance at a given altitude to the total number of gusts per unit time or distance at that altitude.

The analysis procedure for the Design Envelope Approach was as follows: (1) Determine the lowest allowable values of  $\sigma_w \eta_d$  or  $\sigma_v \eta_d$  for the major components of the reference airplane, the 720B, (2) Determine the exceedance ratio for the critical elements or components of the airplane for a particular critical altitude, (3) Establish an acceptable exceedance ratio for each altitude from all design envelope analysis conditions. Determine the limit design  $\sigma_w \eta_d$  for each altitude.

#### Statistical Analysis - Flight Profile Approach

The Flight Profile Approach involves the determination of the average number of times per hour that the limit strengths of the more critical structural components or elements are exceeded. The average number of limit strength exceedances is a weighted average number derived from the estimated airline usage of the 720B airplane.

The average number of limit strength exceedances per hour for a given flight condition is established by determining the number of times per foot travelled that the limit strength envelope is perforated or crossed,  $N_c$ . It is assumed that the number of limit strength exceedances is equal to one-half the number of perforations of the strength envelope. That is, there is one peak value exceeding limit strength for each two crossings. One-half of the number of strength envelope crossings per foot travelled times the airplane velocity in ft. per sec. times 3,600 sec. per hour gives the number of limit strength exceedances per flight hour for a given rms gust intensity  $\sigma_w$  or  $\sigma_v$ . A typical diagram showing the limit strength exceedances per ft. travelled for various rms gust intensities is shown in Fig. 21.

In order to account for the variation in rms gust intensity, the limit strength exceedances per hour is multiplied by the probability density function for rms gust velocity as shown in Fig. 22. The integral of this new probability function over all  $\sigma_w$  is,  $\bar{G}$ , the expected number of limit strength exceedances per hour. That is,

$$\bar{G} = 1800V \int_0^{\infty} N_c \hat{f}(\sigma_w) d\sigma_w. \quad (16)$$

The limit strength exceedances per hour for the representative flight profiles is obtained by multiplying the exceedances per hour for each flight condition in the profile by the fraction of the total profile time spent at that condition, and then summing the exceedances per hour for all conditions in the particular profile.

The exceedances per average flight hour for total airplane usage is then determined by weighting the exceedances per hour of each profile by the fraction of total airplane usage represented by the particular profile and then summing over all the profiles. This process is represented by the following equation:

$$N_P = \sum_k \left[ \sum_j \bar{G}_j \frac{t_j}{t_T} \right] t_k \quad (17)$$

where

$N_P$  total airplane exceedances per average flight hour  
 $\bar{G}_j$  exceedances per hour for a particular flight condition



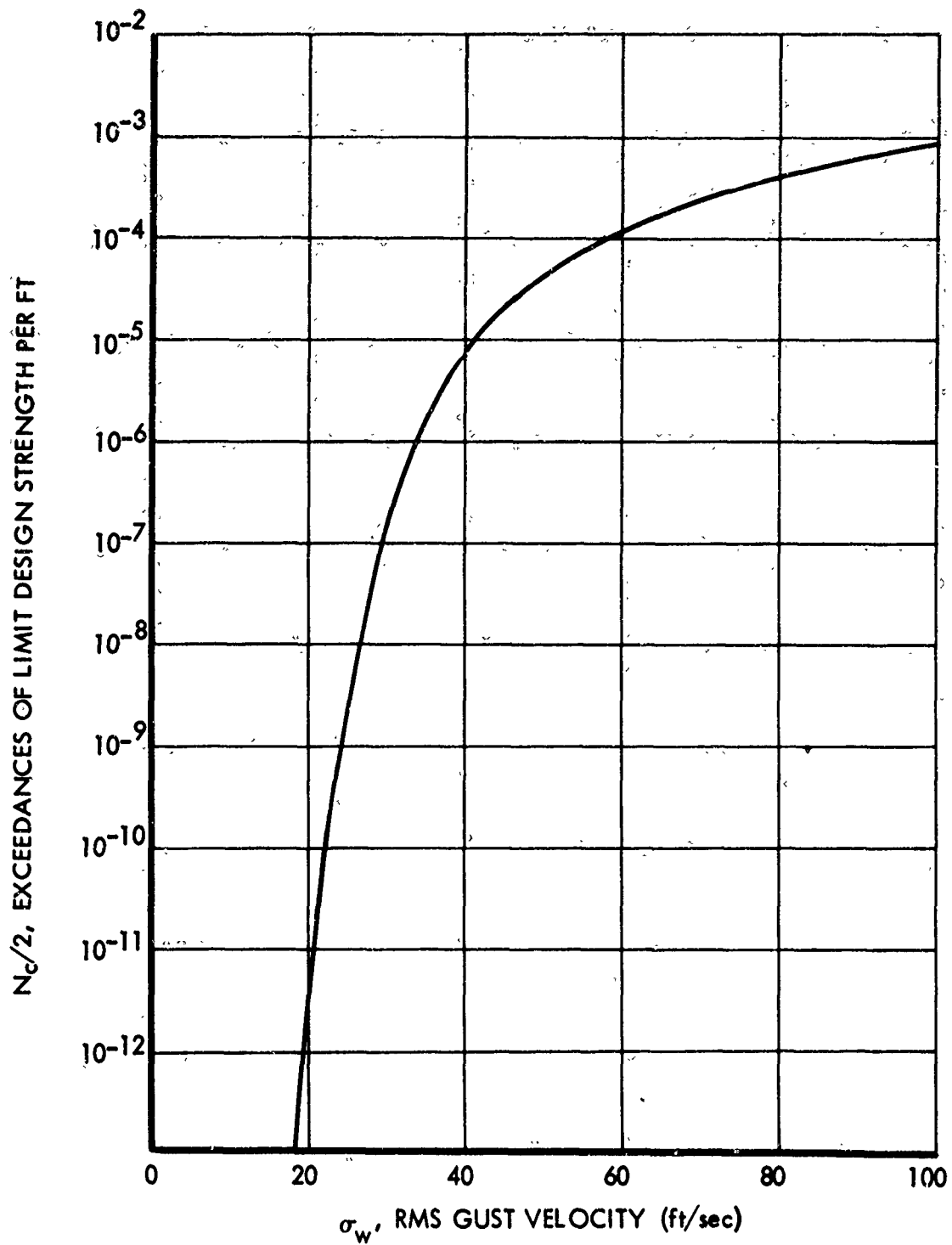


FIGURE 21. EXCEEDANCES OF LIMIT DESIGN STRENGTH PER FT. TRAVELED

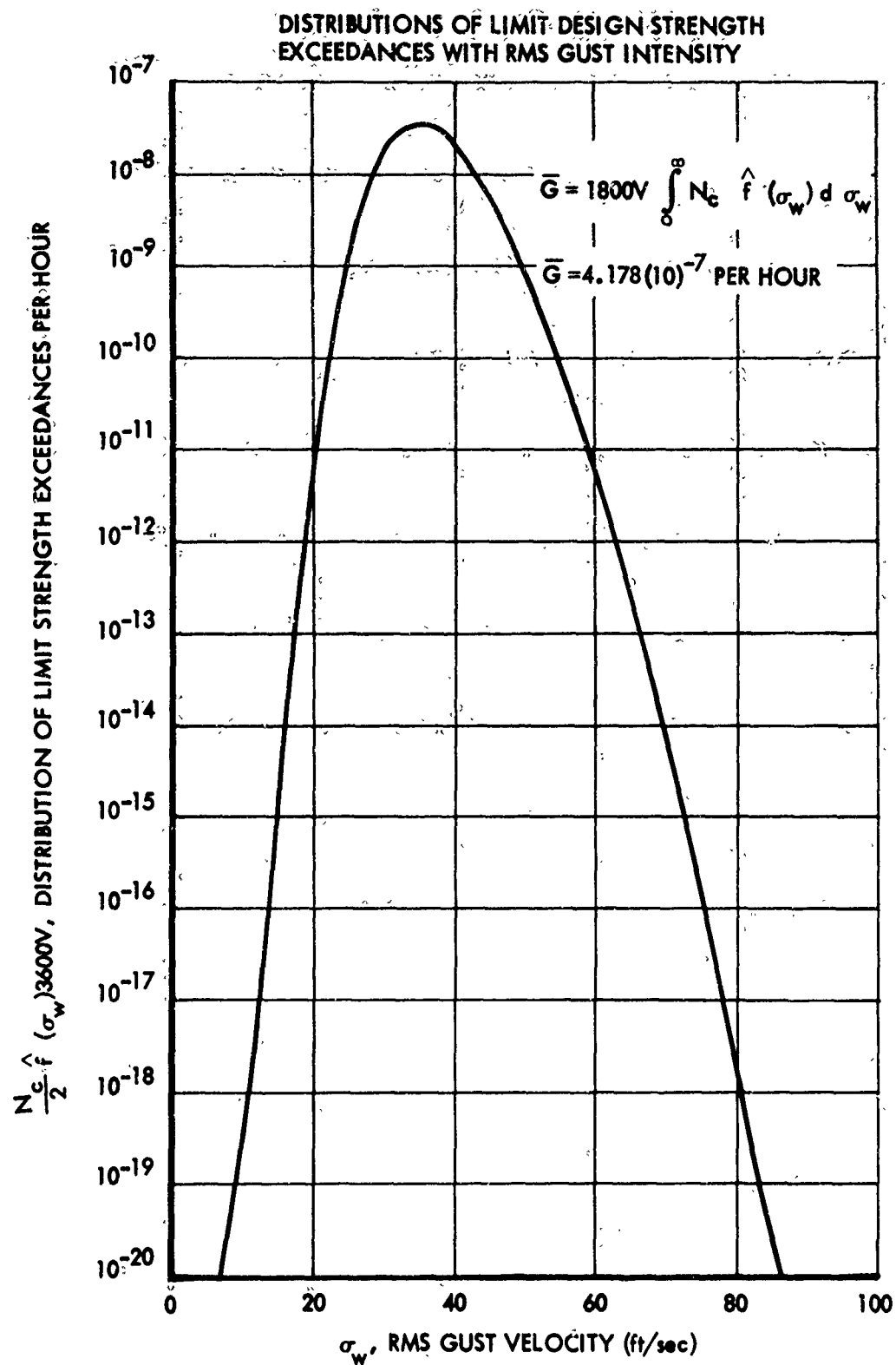


FIGURE 22. DISTRIBUTIONS OF LIMIT DESIGN STRENGTH  
EXCEEDANCES WITH RMS GUST INTENSITY

$t_j$  the time spent at a particular flight condition  
 $t_T$  the total profile flight time  
 $t_k$  fraction of total airplane usage represented by a particular profile  
 $j$  the number of conditions in a particular profile  
 $k$  the number of profiles used to represent the airplane usage

## RESULTS

### General Remarks

In the past, airplane power spectral gust analyses results have been used to determine the effects of airplane dynamic responses on the bending moments, shears, and torsions for the major components of an airplane. These incremental loads, usually the wing bending moments, were compared with comparable loads from a static aeroelastic analysis, using the gust load formula, to arrive at a dynamic factor. Then, the dynamic factor was applied to other aeroelastic solutions to obtain design incremental loads for all gust design conditions.

The basic results of a power spectral analysis, the rms loads,  $\bar{A}$ , and the number of times these loads cross their mean values with positive (or negative) slope per sec. or per ft.,  $N_0$ , are not in themselves adequate to assess airplane strength. However, the bending moments, shears, and torsions, and the incremental cg accelerations do provide insight into an airplane dynamic responses in rough air, and can be used as guides to ascertain critical locations in the airplane structure. Then, the properly phased combined effects of the bending moments, shears, and torsions should be used to assess the strength at these critical locations.

The rms bending moments, shears, and torsions for the 720B airplane were determined at the locations indicated in Figs. 23 and 24 for the vertical and lateral analyses, respectively. The combined effects of vertical and lateral gust loads were studied for two locations on the aft fuselage, Body Balance Stations 1000 and 1280. Stress analyses were conducted for the most critical locations on the wing, fuselage, and the vertical tail. These locations consisted of one wing location, Wing Station 360 at Body Buttock Line 260 or 33 percent of the wing semi-span ( $\eta = .33$ ). The stresses were studied for three body locations, Body Balance Stations 480, 1000, and 1280. One location on the vertical tail, Fin Station 165.5, Elastic Axis (EA) Station 158 was investigated.

### Correlation of Dynamic and Aeroelastic Analyses

The total loads and stresses that were used to assess the airplane strength resulted from the incremental dynamic loads and the one-factor level flight loads. The level flight loads were obtained from aeroelastic solutions,<sup>(6,7)</sup> and the incremental dynamic loads were obtained from power spectral analysis. In order to determine if these two independent solutions represented the airplane in a consistent manner, the one-factor level flight loads were obtained for one analysis condition, Condition 1, using the dynamic analysis equations of motion. This was

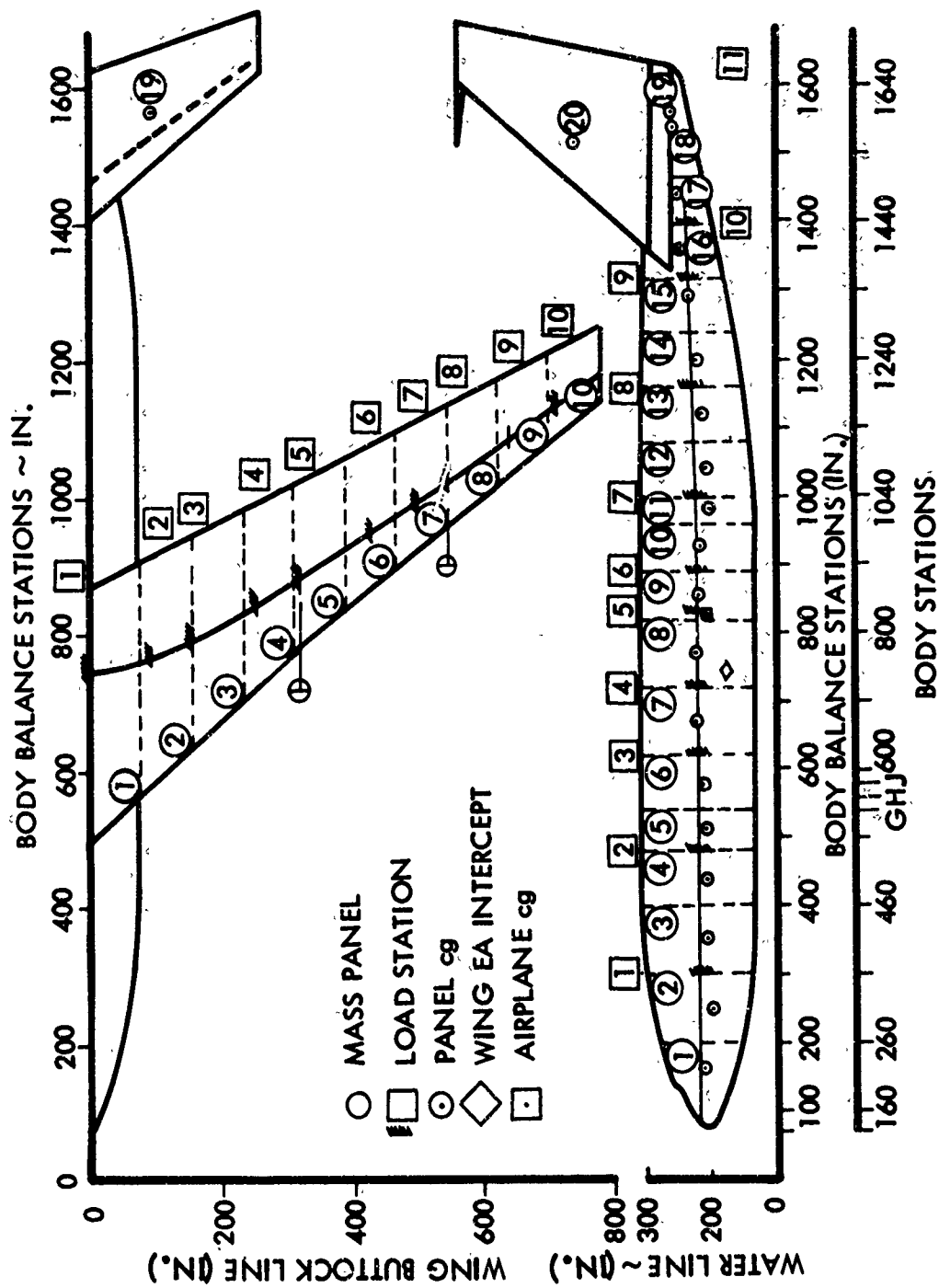


FIGURE 23. MODEL IDEALIZATION - VERTICAL ANALYSES

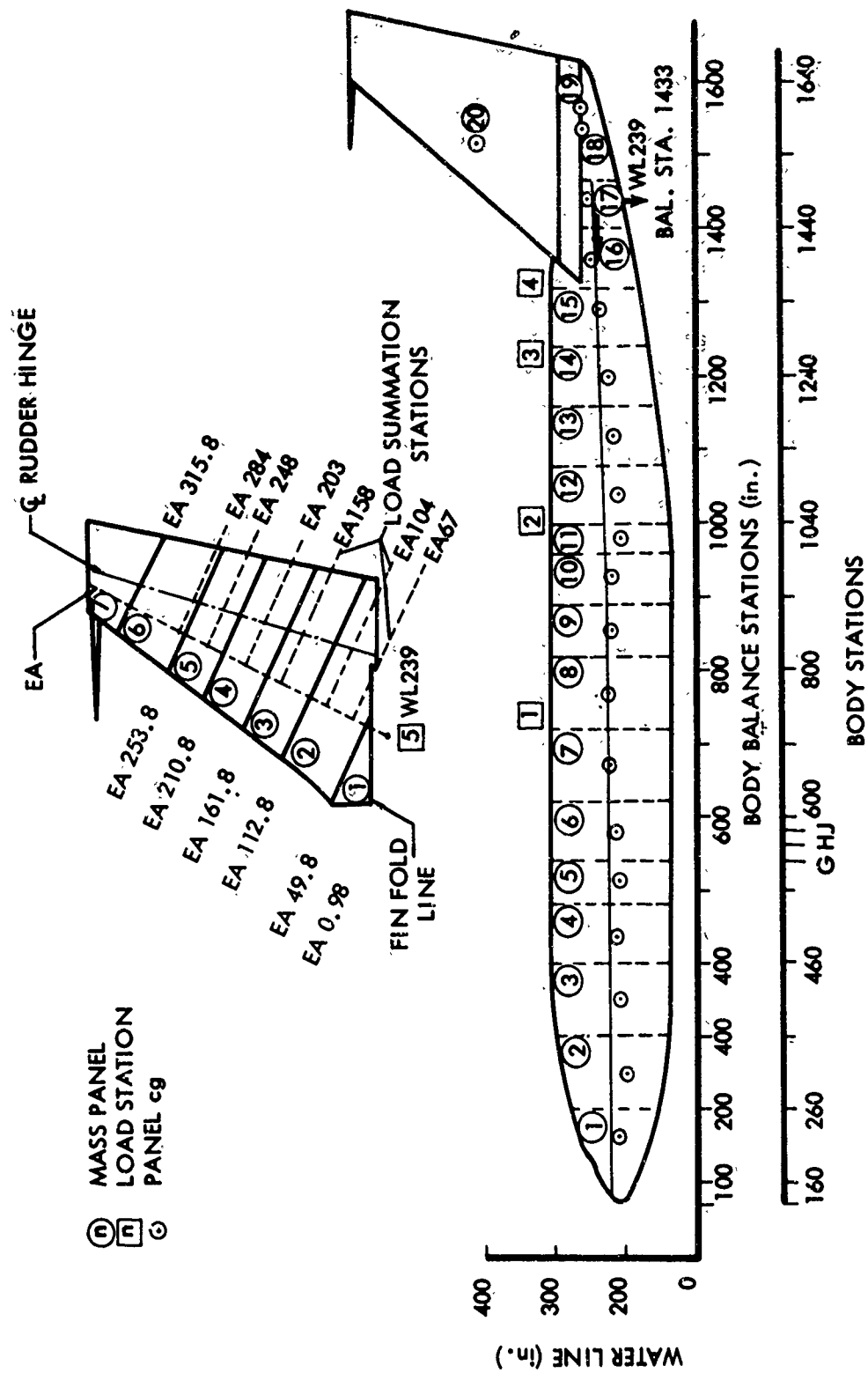


FIGURE 24. MODEL IDEALIZATION - LATERAL ANALYSIS

accomplished by setting the pitch and flexible generalized coordinate accelerations, the pitch and translation displacements, and all of the generalized coordinate velocities equal to zero. The vertical translation acceleration was set at  $1.0g$ . In order to allow for a force balance in the vertical translation equation and a moment balance in the pitch equation, two unknowns were introduced to replace the airplane pitch and translation displacement freedoms. One of the unknowns was the angle of attack which gives rise to the lift necessary to offset the airplane weight plus the balancing tail load. The other unknown was the horizontal tail load which must balance the airplane pitching moments.

The wing bending moments, shears, and torsions, and the wing static deflections resulting from the reduced dynamic solution were obtained to compare with corresponding values from the aeroelastic solution. The aeroelastic wing loads shown in this comparison were obtained by subtracting a zero load factor solution from a one-factor solution. The comparison is made on the basis of a static incremental one-factor load. The results in Fig. 25 show the wing bending deflections obtained from the two solutions. The wing bending moment, shear, and torsion loads are compared in Fig. 26. The angle of attack required for level flight was  $4.27$  degrees for the reduced dynamic solution and  $4.32$  for the aeroelastic solution.

#### Frequency Response Functions

The equations of motion were solved to obtain steady state complex frequency response functions for the generalized coordinates due to  $1.0$  ft. per sec. sinusoidal gust excitation. Examples of the modulus of these frequency response functions for the Vertical Analyses, Condition 24, are presented in Figs. 27(a) through 27(j). The response quantities are identified as  $q_1$  through  $q_7$  for the seven free-free airplane symmetrical modes and  $q_T$ ,  $q_P$  and  $q_X$  for the rigid airplane freedoms of vertical translation, pitch, and fore and aft translation, respectively. These frequency response functions illustrate the predominate responses for each individual generalized coordinate, and indicate the coupling that exists between the coordinates. The frequency response curve for airplane pitch, Fig. 27(i), shows the well damped airplane short period or pitch mode at  $0.36$  cps;  $0.028$  rad. per ft. The airplane pitch response has a large effect on the airplane loads, because of the high energy in atmospheric turbulence within this frequency range.

Typical generalized coordinate response curves for the lateral analyses, Conditions 10 and 10YD, are shown in Fig. 28(a) through 28(i) both with and without the yaw damper operating. The Dutch roll response at  $0.20$  cps or  $0.0015$  rad. per ft. is the major contributor to the lateral loads. Thus, the changes which effect the Dutch roll response have a large effect

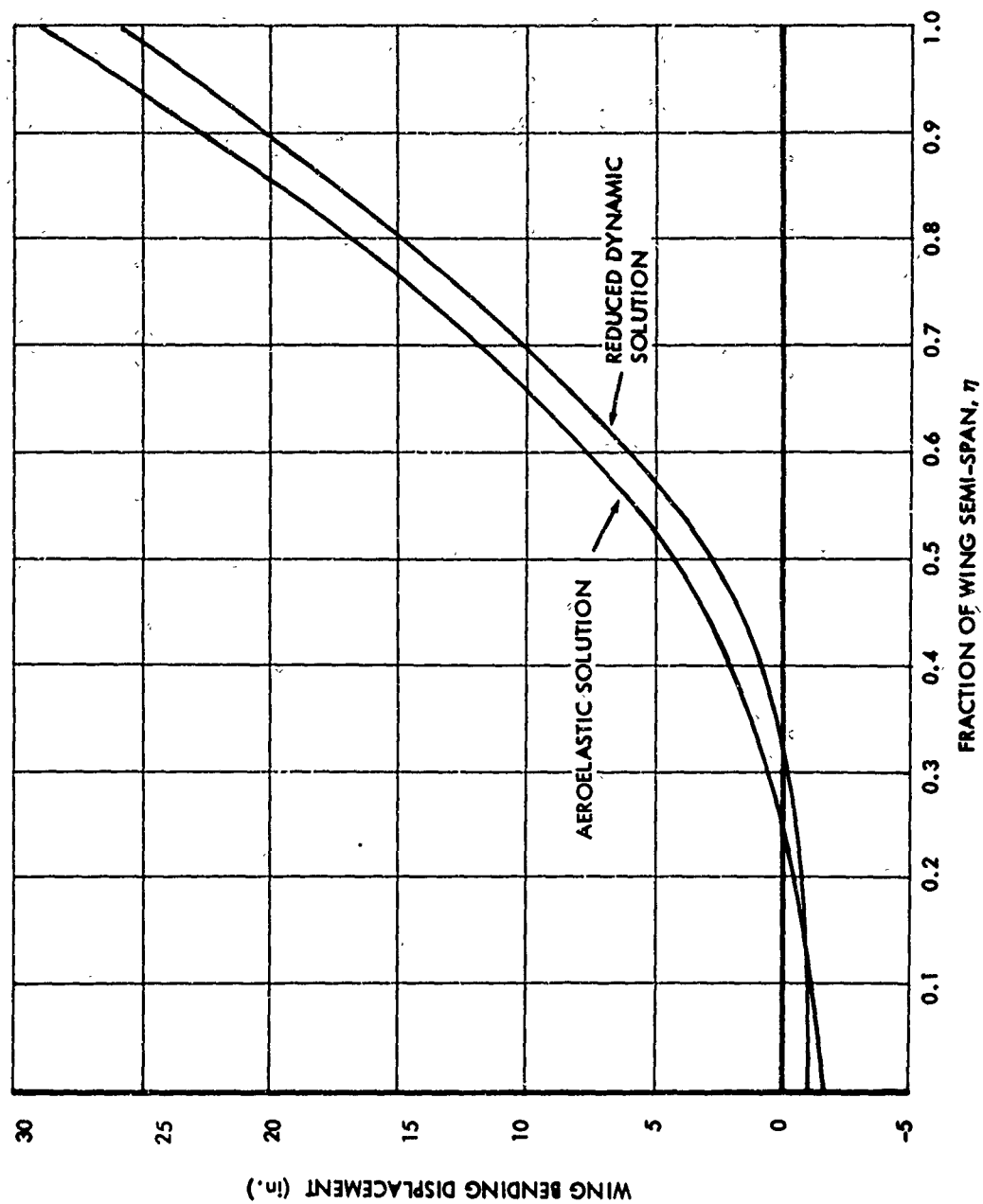


FIGURE 25. COMPARISON OF WING DEFLECTIONS FOR AEROELASTIC AND REDUCED DYNAMIC SOLUTIONS



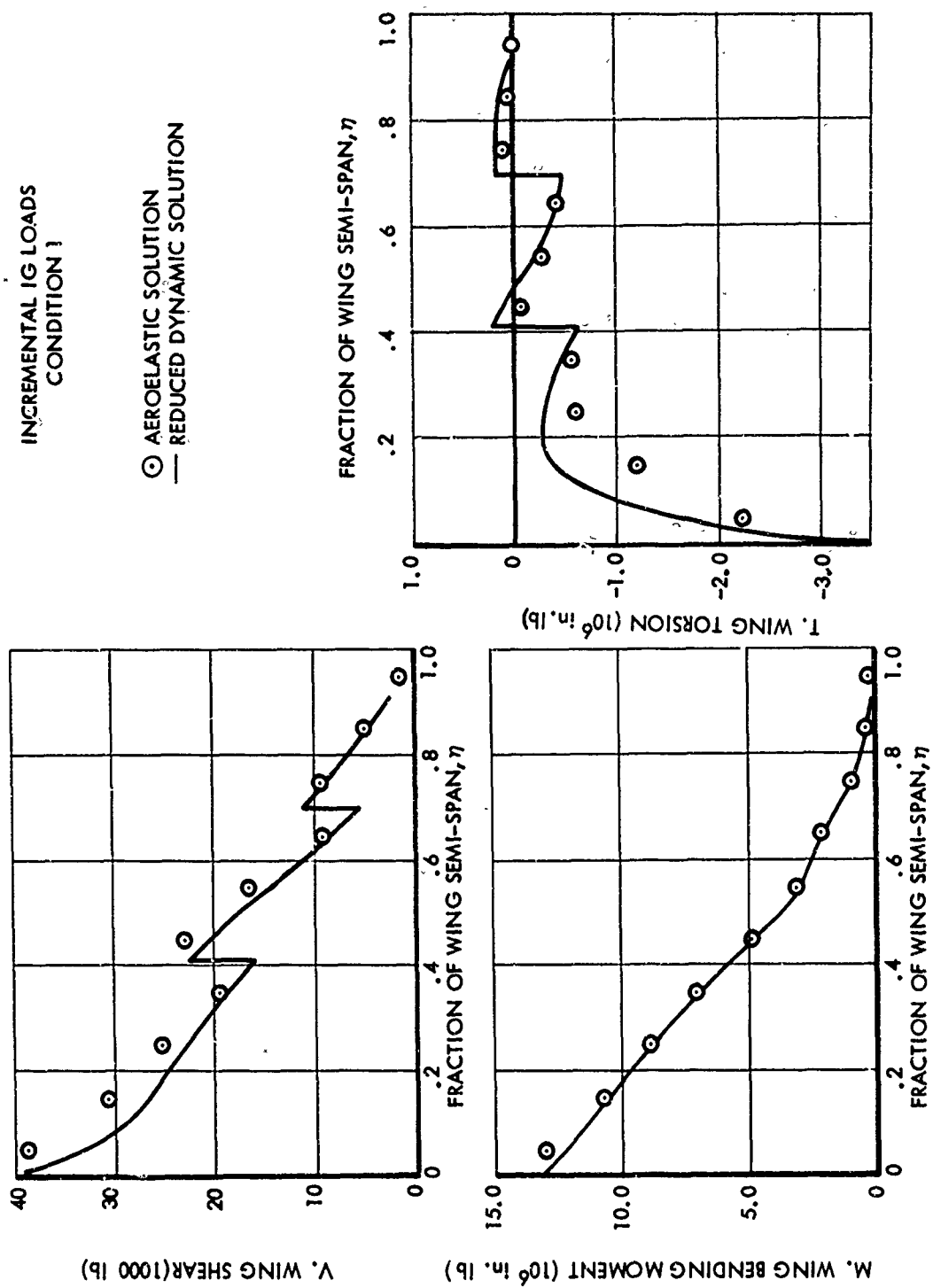


FIGURE 26. COMPARISON OF WING LOADS FOR AEROELASTIC AND REDUCED DYNAMIC SOLUTIONS

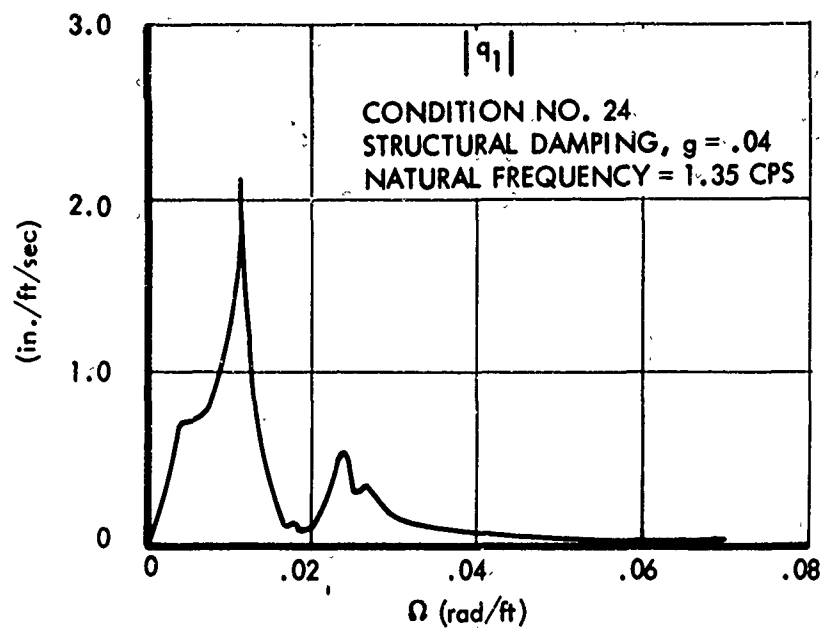


FIGURE 27a. FREQUENCY RESPONSE, FIRST SYMMETRICAL AIRPLANE MODE

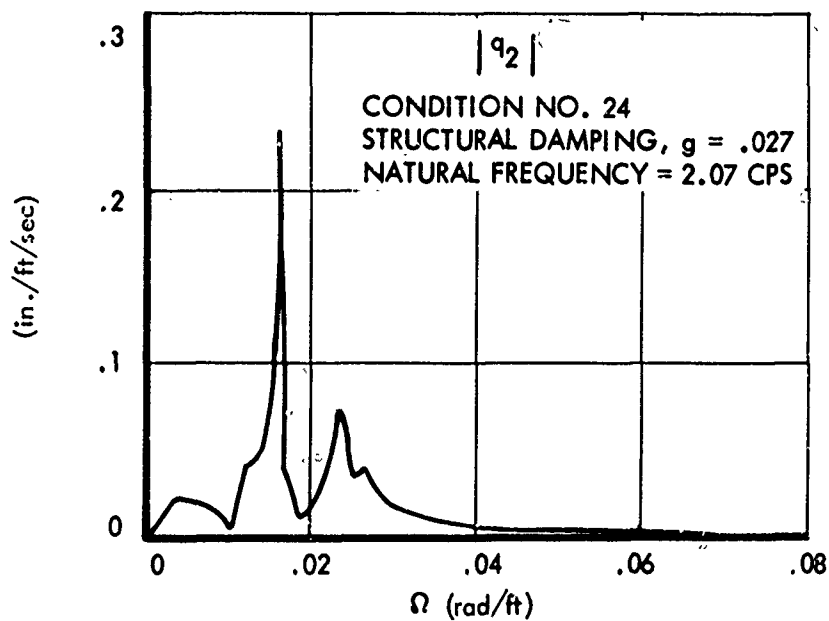


FIGURE 27b. FREQUENCY RESPONSE, SECOND SYMMETRICAL AIRPLANE MODE

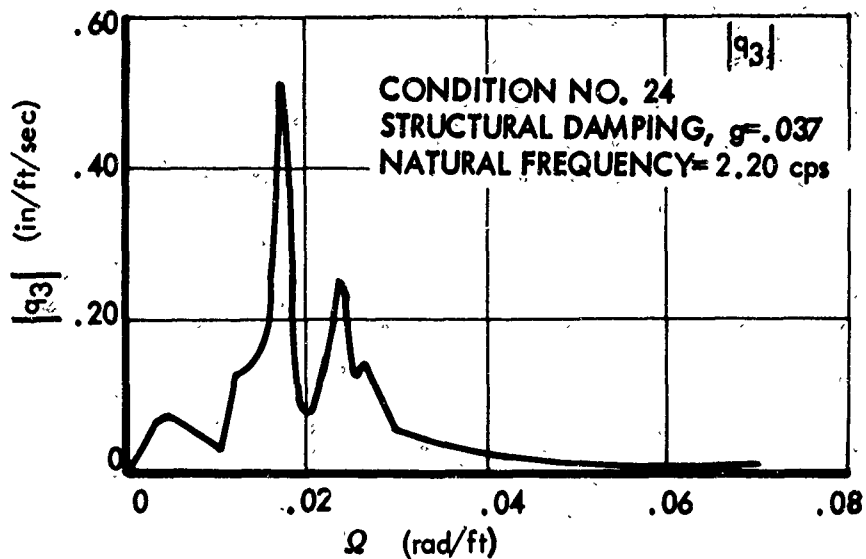


FIGURE 27c. FREQUENCY RESPONSE, THIRD SYMMETRICAL AIRPLANE MODE

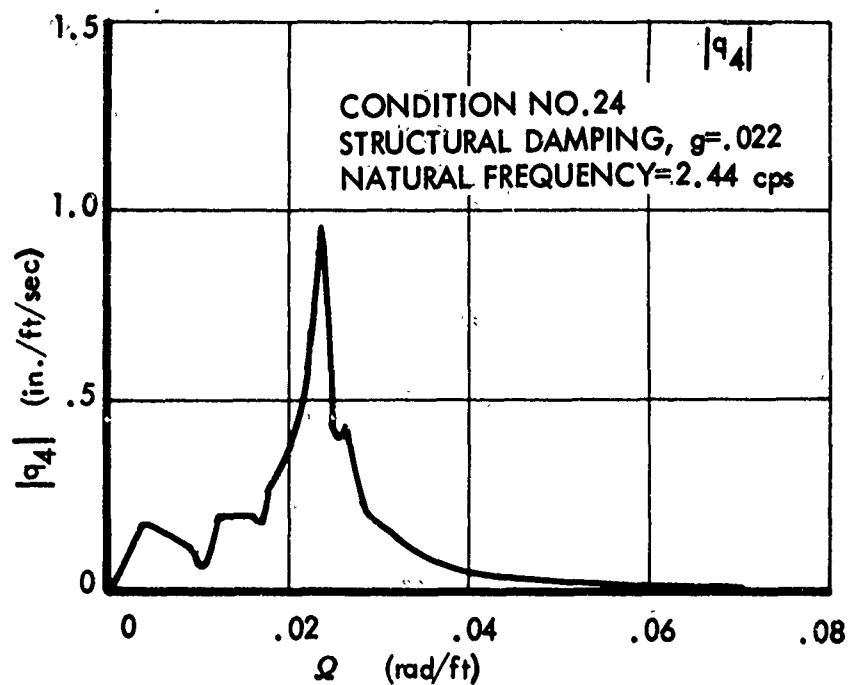


FIGURE 27d. FREQUENCY RESPONSE, FOURTH SYMMETRICAL AIRPLANE MODE

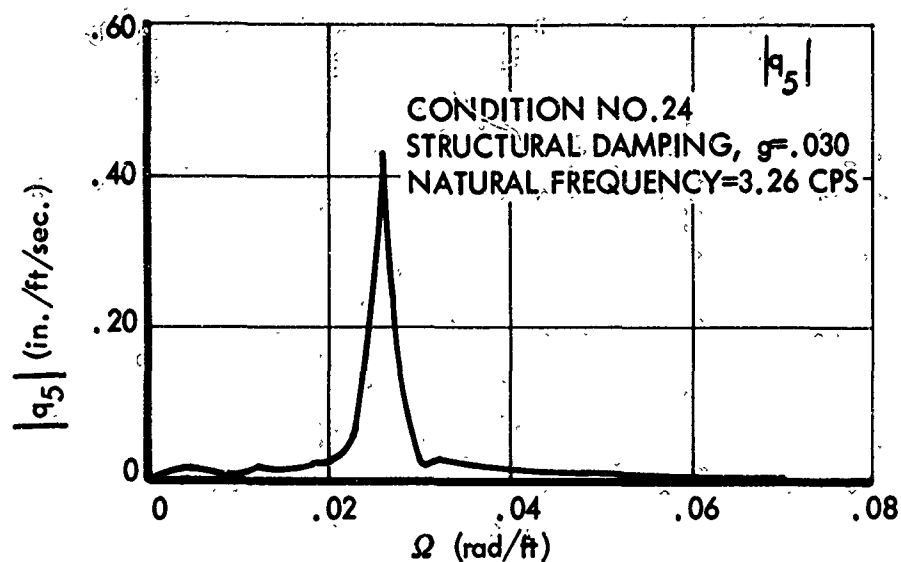


FIGURE 27e. FREQUENCY RESPONSE, FIFTH SYMMETRICAL AIRPLANE MODE

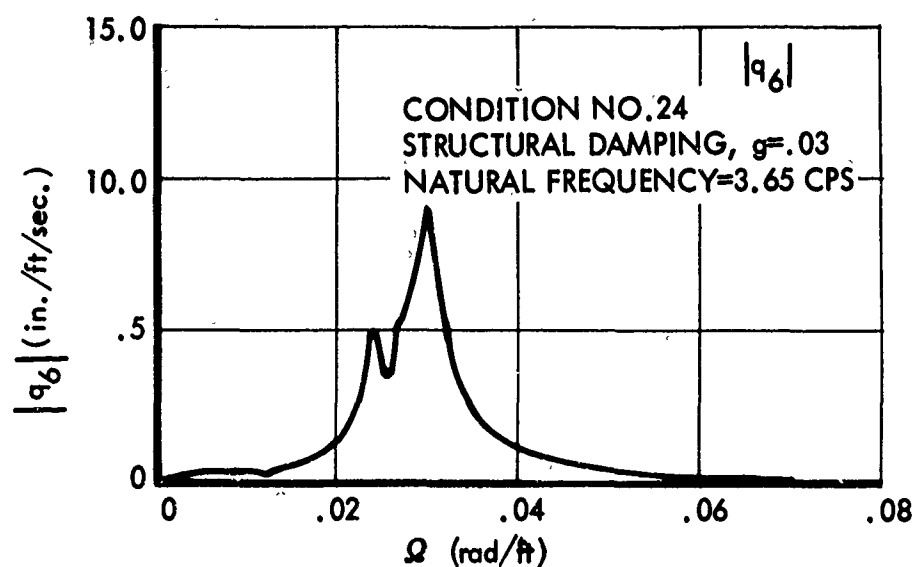


FIGURE 27f. FREQUENCY RESPONSE, SIXTH SYMMETRICAL AIRPLANE MODE

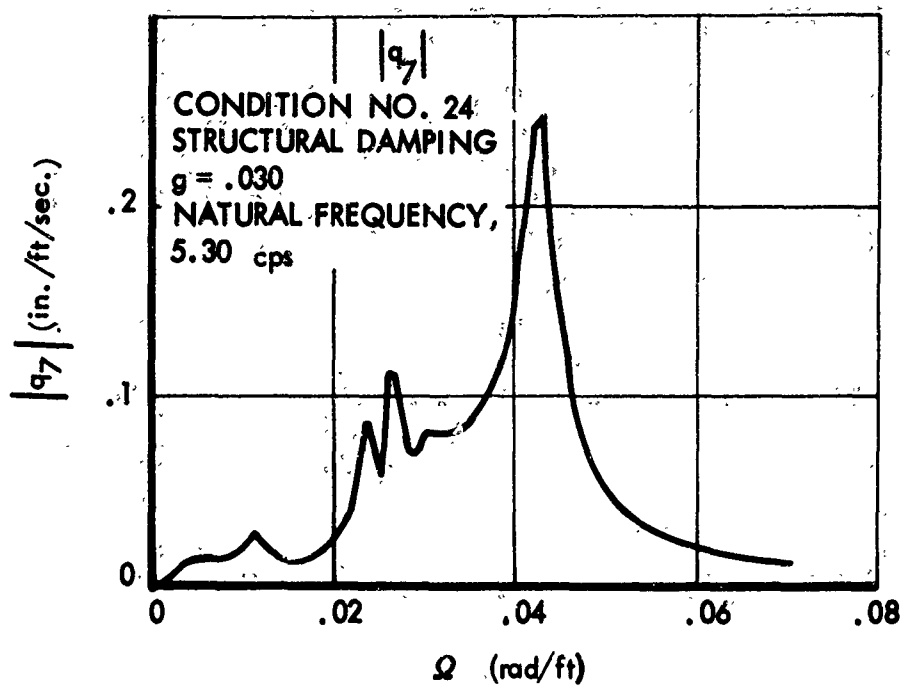


FIGURE 27g. FREQUENCY RESPONSE, SEVENTH SYMMETRICAL AIRPLANE MODE

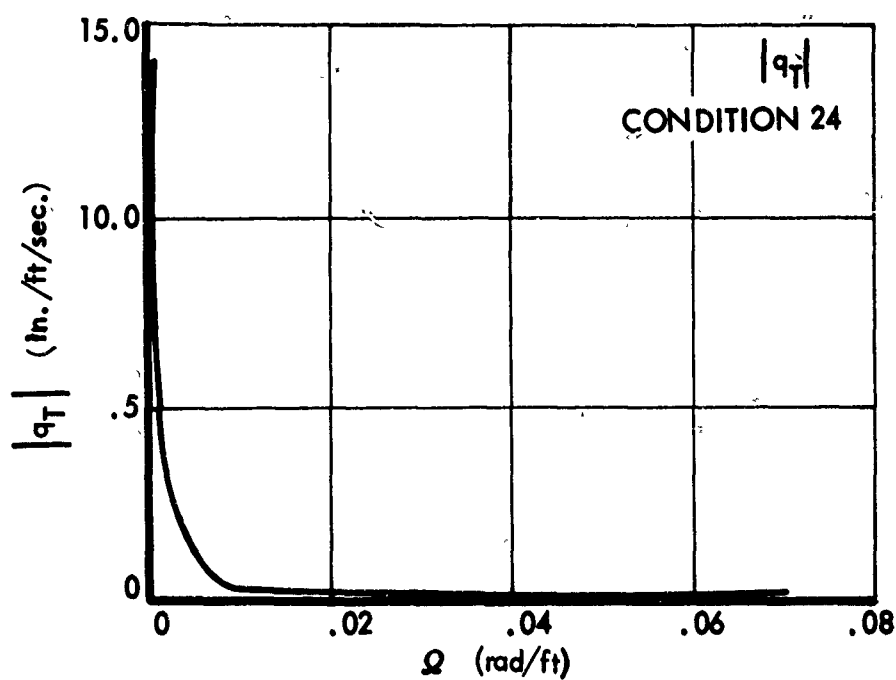


FIGURE 27h. FREQUENCY RESPONSE, AIRPLANE VERTICAL TRANSLATION

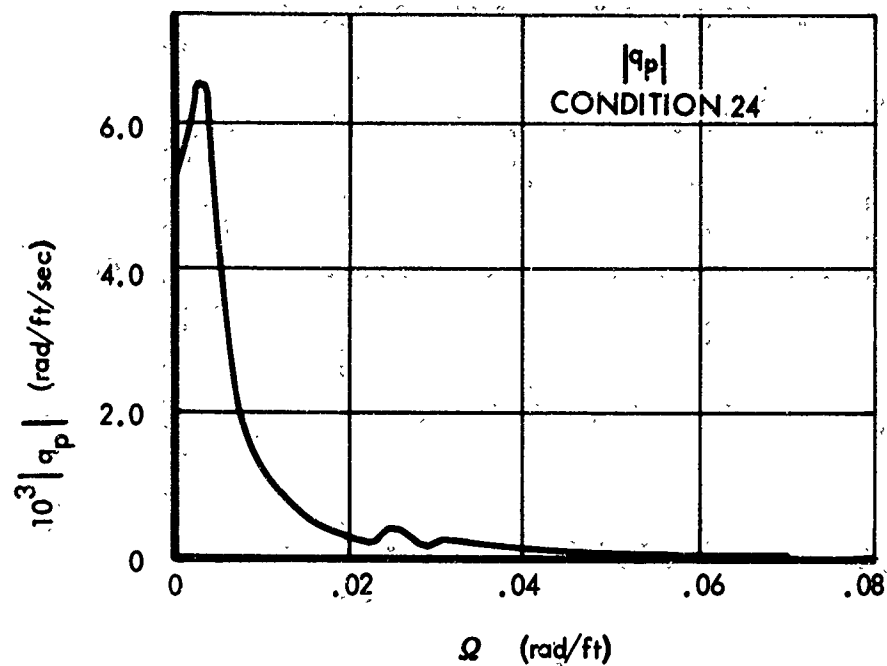


FIGURE 27i. FREQUENCY RESPONSE, AIRPLANE PITCH

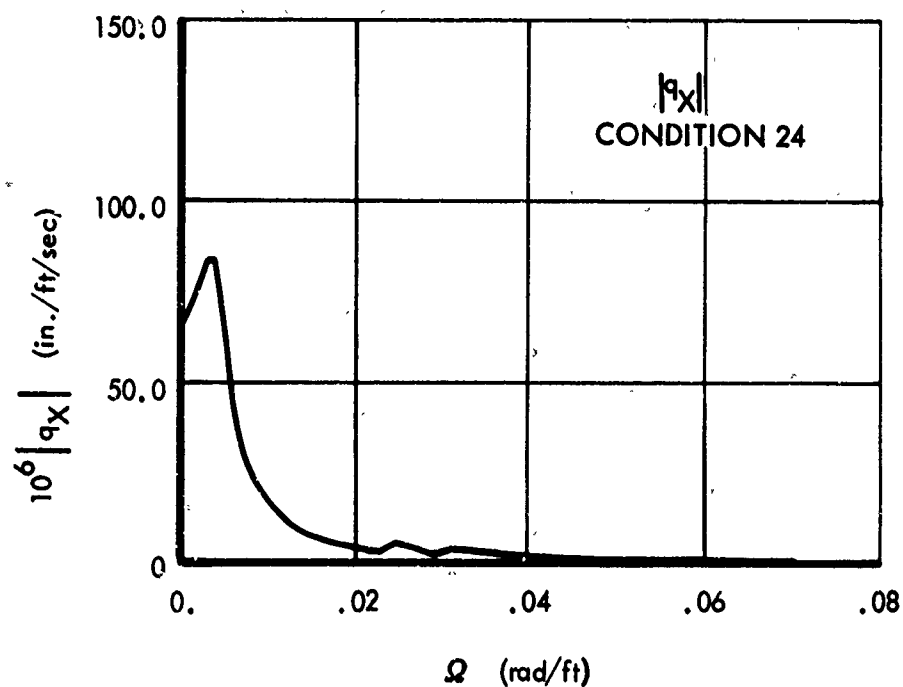


FIGURE 27j. FREQUENCY RESPONSE, AIRPLANE FORE AND AFT TRANSLATION

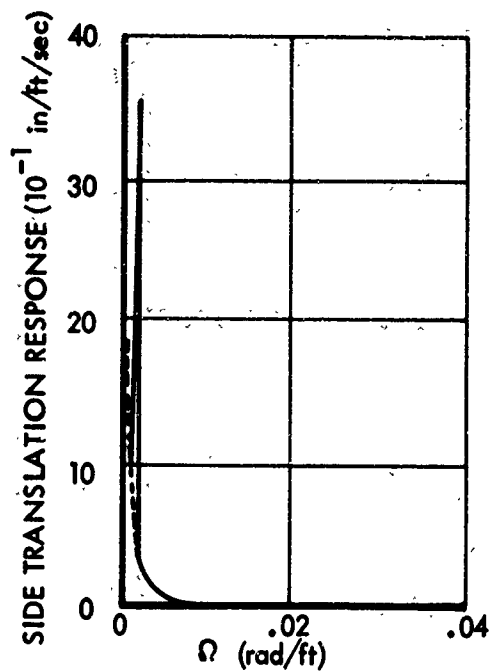


FIGURE 28a. FREQUENCY RESPONSE, AIRPLANE SIDE TRANSLATION

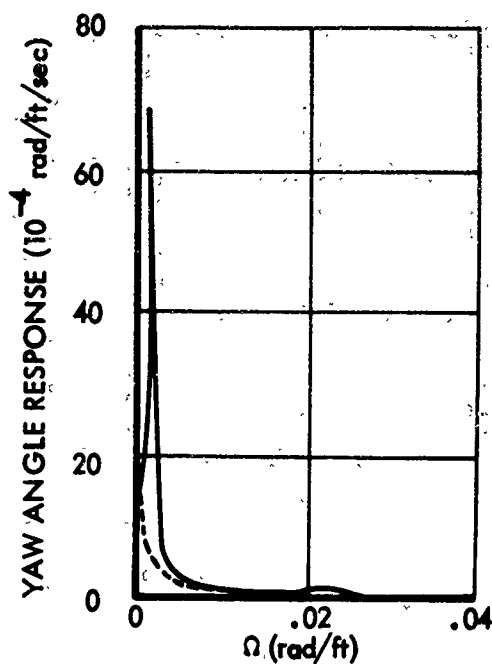


FIGURE 28b. FREQUENCY RESPONSE, AIRPLANE YAW

NOTE:

----- YAW DAMPER ON  
 ————— YAW DAMPER OFF  
 CONDITION 10, 10 YD

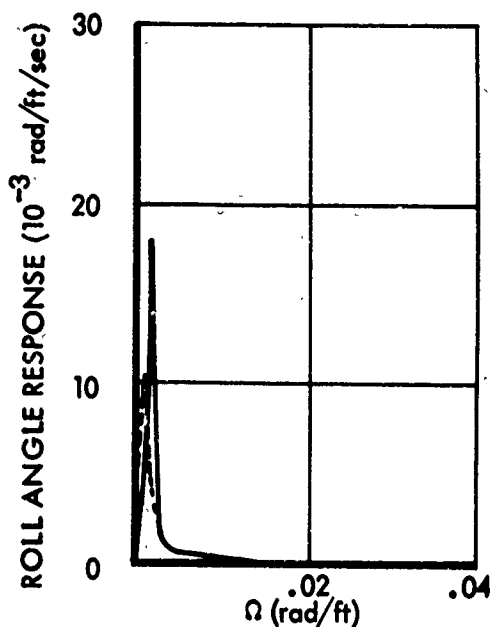


FIGURE 28c. FREQUENCY RESPONSE, AIRPLANE ROLL

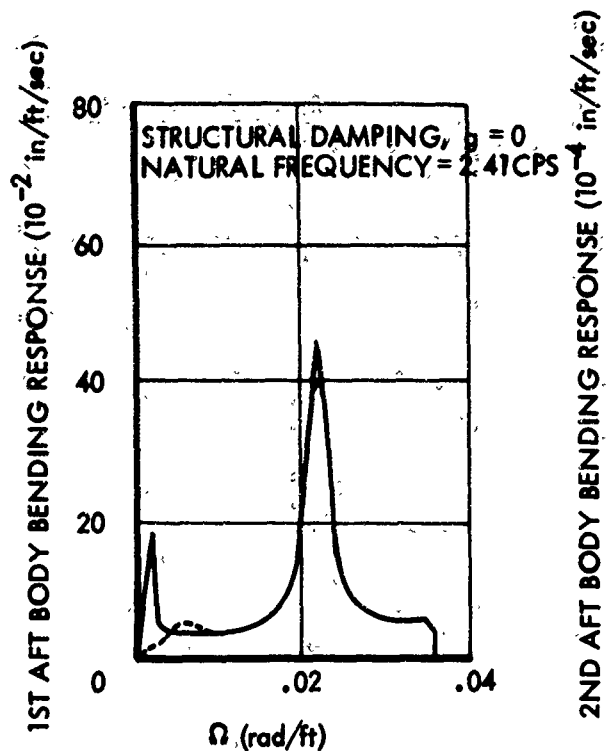


FIGURE 28d. FREQUENCY RESPONSE, FIRST CANTILEVERED AFT BODY SIDE BENDING MODE

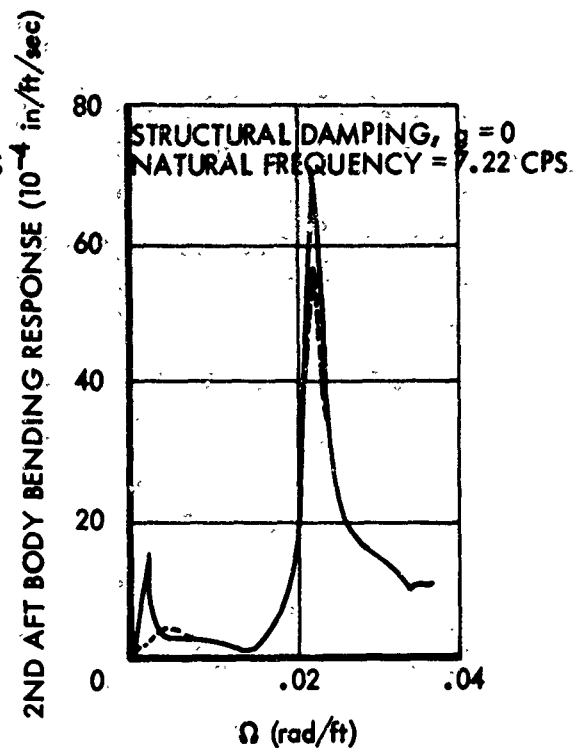


FIGURE 28e. FREQUENCY RESPONSE, SECOND CANTILEVERED AFT BODY SIDE BENDING MODE

NOTE:

----- YAW DAMPER ON

———— YAW DAMPER OFF

CONDITION 10, 10 YD

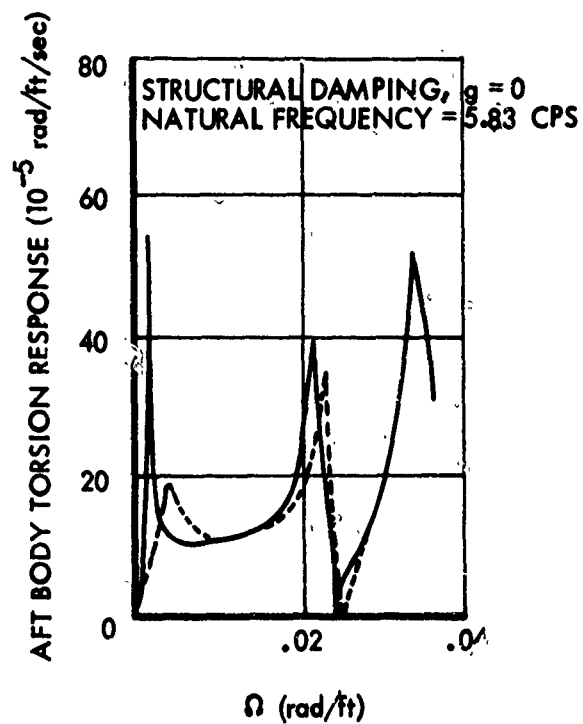


FIGURE 28f. FREQUENCY RESPONSE, FIRST CANTILEVERED AFT BODY TORSION MODE



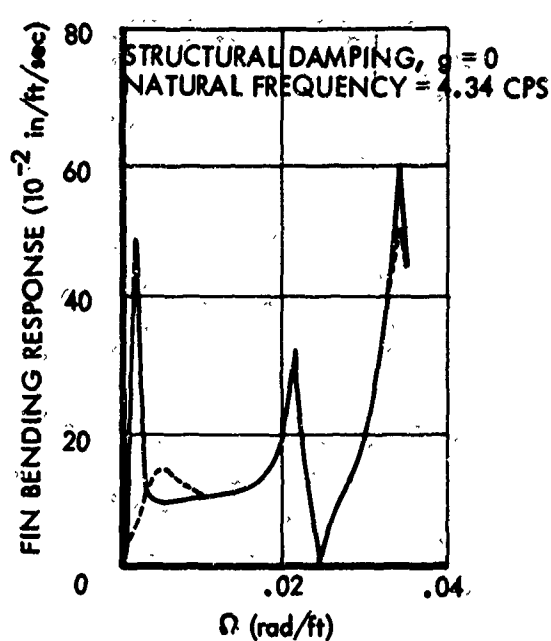


FIGURE 28g. FREQUENCY RESPONSE, FIRST CANTILEVERED FIN BENDING MODE

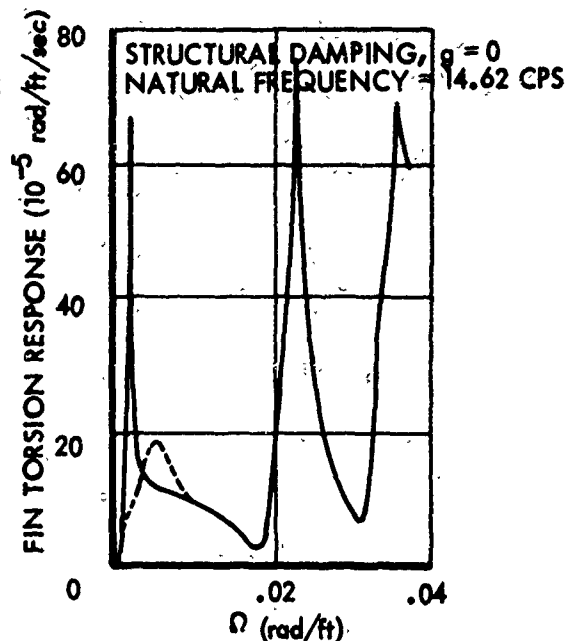


FIGURE 28h. FREQUENCY RESPONSE, FIRST CANTILEVERED FIN TORSION MODE

NOTE:

----- YAW DAMPER ON

———— YAW DAMPER OFF

CONDITION 10, 10 YD

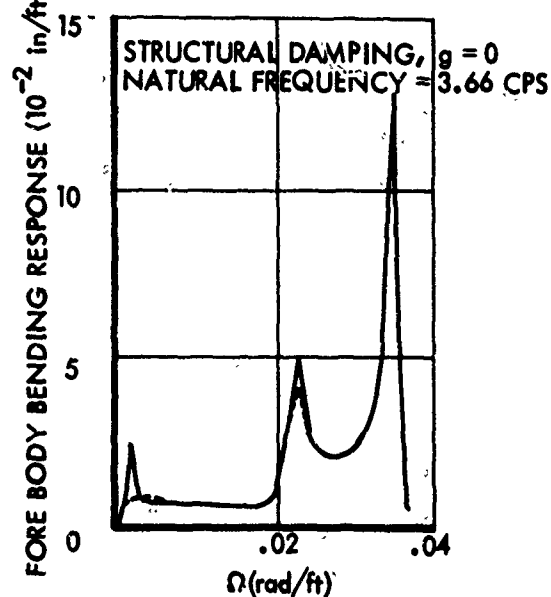


FIGURE 28i. FREQUENCY RESPONSE, FIRST FORE BODY CANTILEVERED SIDE BENDING

on magnitudes of the lateral loads. When the yaw damper is engaged, the rudder is commanded by the yaw damper servo system and will deflect in a manner to provide positive damping in the Dutch roll mode. The results of the yaw damper operation is readily apparent. By observing the decrease in the rigid airplane yaw response not only are the frequency response functions for the rigid airplane motions attenuated, but the frequency at which the maximum response occurs is reduced. This is reasonable, because at the Dutch roll frequency, 0.07 cps, the phase shift through the yaw damper system causes the rudder displacement to lead the yaw rate signal. This results in a rudder deflection that reduces the fin aerodynamic force due to yawing displacement which, in turn, causes a reduced Dutch roll resonant frequency.

The coupling between the flexible modes and the Dutch roll mode occurs at a higher frequency with the autopilot engaged. This may seem to contradict the effect evidenced by the rigid airplane response; however, this difference does exist, and there is a logical explanation. The explanation again lies with the phasing of the rudder deflection caused by the yaw damper output. In this case, the frequency, .63 cps, 0.0046 rad. per ft., is such that the rudder displacement lags the yaw rate signal; therefore, the rudder deflection adds to the fin aerodynamic force. This increase in force results in a larger flexible mode excitation at this frequency. As the response frequency increases toward a structural resonance frequency the cut-off filter in the yaw damper amplifier system attenuates the yaw damper output so that self-excitation will not occur.

Complex frequency responses for the loads were obtained by substituting the complex generalized coordinate responses into the airplane load equations. These load equations sum the incremental inertia loads, the airloads resulting from the coordinate responses, and the applied gust loading. Fig. 29 shows the load responses for Vertical Analyses, Condition 24, for wing bending moment, shear, and torsion at the most critical wing station, Wing Eta Station 0.33. Similar load frequency response functions are shown for Wing Eta Station 0.12. Fuselage vertical shear and bending moment frequency responses at the critical forward body station, Body Station 540 and at Aft Body Station 1360, are shown in Fig. 30.

Fig. 31 gives the vertical tail load frequency responses for lateral analysis Conditions 10 and 10YD. These frequency responses are for vertical tail bending moment, shear, and torsion at the vertical tail Elastic Axis Stations 67 and 158 with and without the yaw damper operating. Fig. 32 shows the lateral bending moment, shear, and torsion frequency response functions for Body Station 1375 with and without the yaw damper operating.

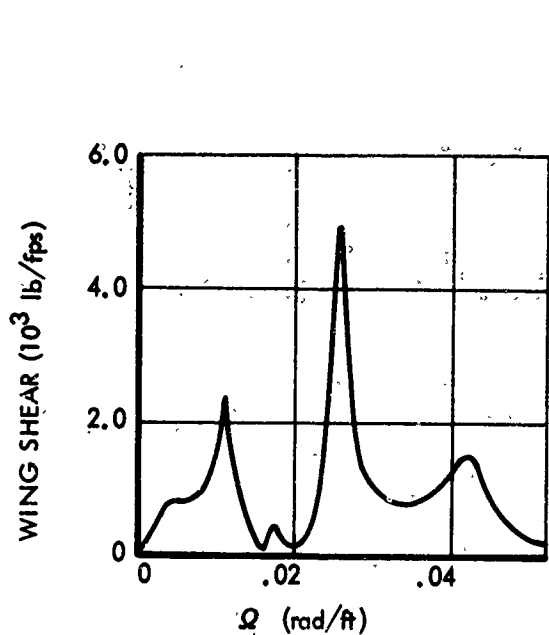


FIGURE 29a. FREQUENCY  
RESPONSE, WING  
VERTICAL SHEAR

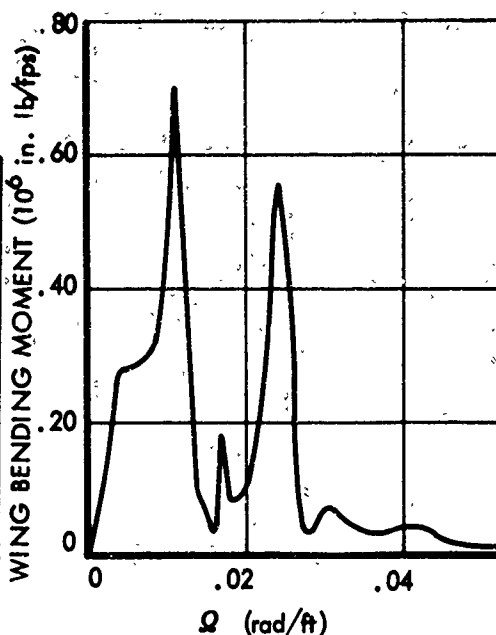


FIGURE 29b. FREQUENCY  
RESPONSE, WING  
BENDING MOMENT

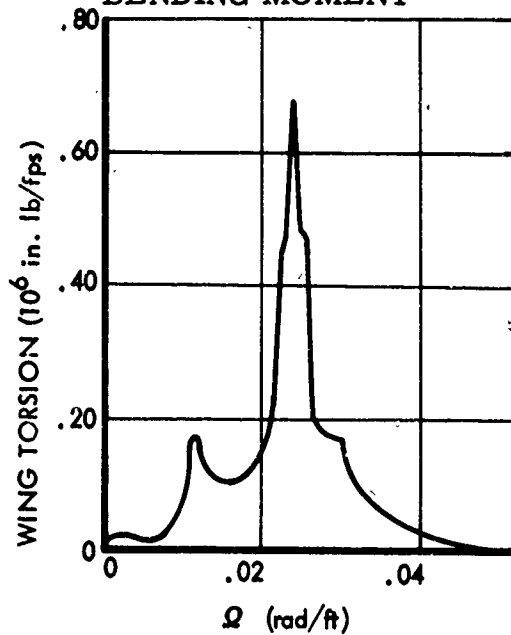


FIGURE 29c. FREQUENCY  
RESPONSE, WING TORSION

NOTE: CONDITION 24 WING STATION,  
 $\eta = 0.33$

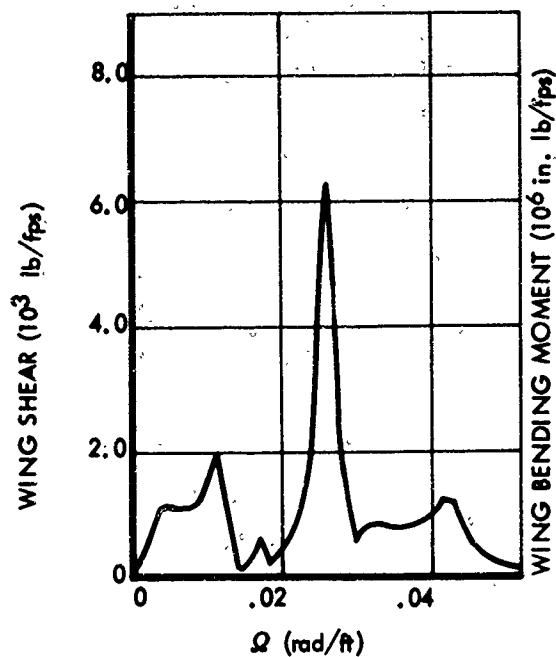


FIGURE 29d. FREQUENCY RESPONSE, WING VERTICAL SHEAR

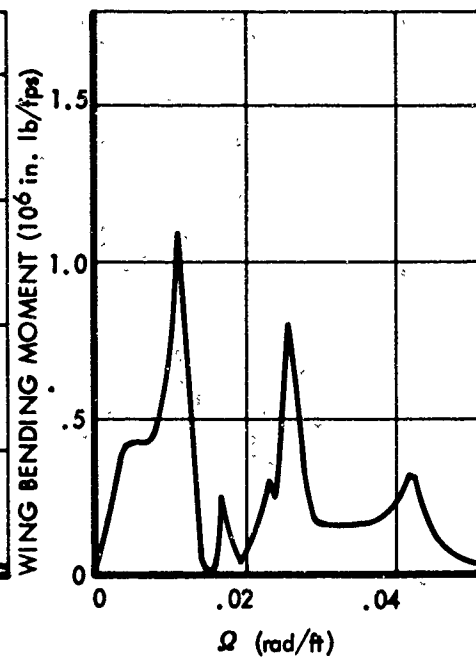


FIGURE 29e. FREQUENCY RESPONSE, WING BENDING MOMENT

NOTE: CONDITION 24 WING STATION  $\eta = 0.12$

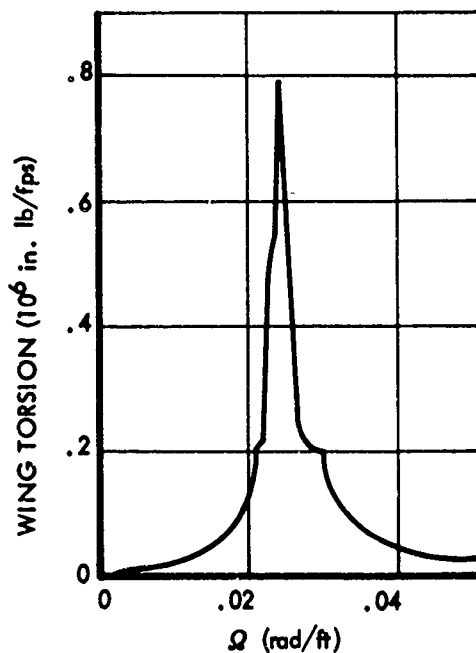


FIGURE 29f. FREQUENCY RESPONSE, WING TORSION

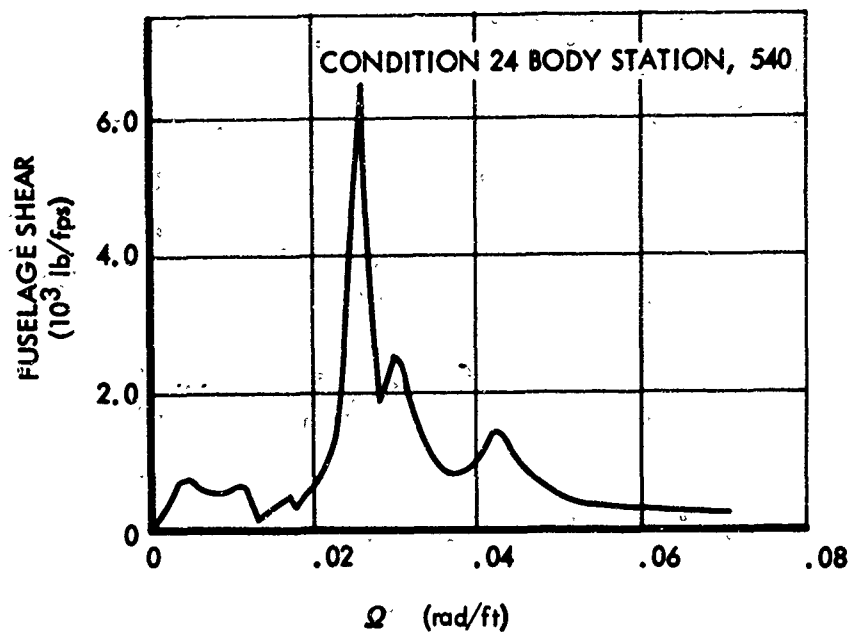


FIGURE 30a. FREQUENCY RESPONSE, FUSELAGE VERTICAL SHEAR

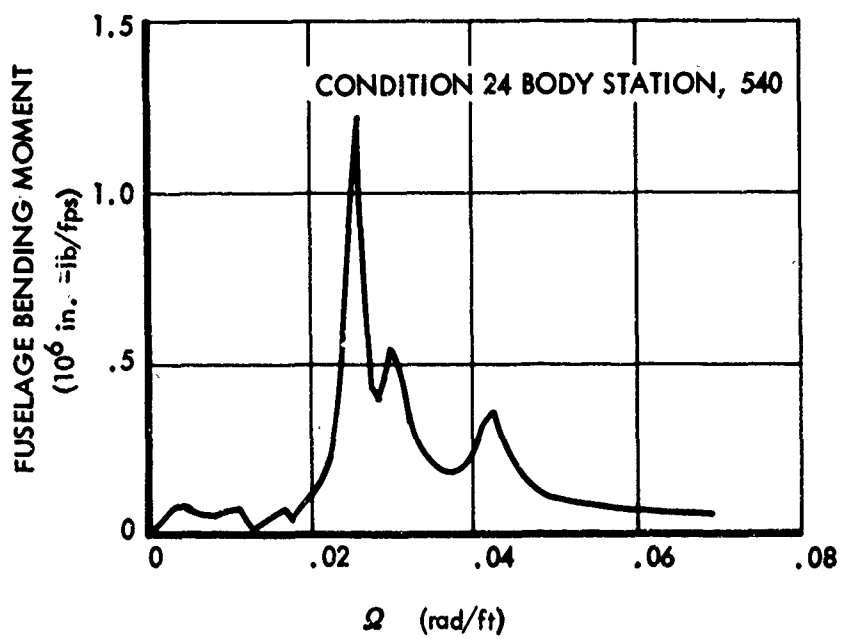


FIGURE 30b. FREQUENCY RESPONSE, FUSELAGE VERTICAL BENDING MOMENT

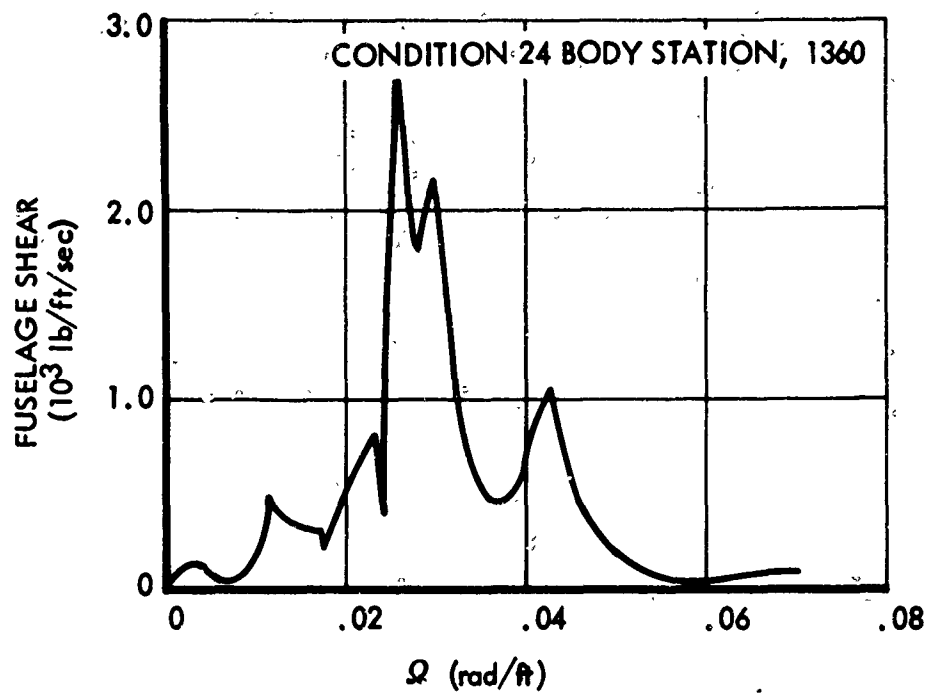


FIGURE 30c. FREQUENCY RESPONSE, FUSELAGE VERTICAL SHEAR

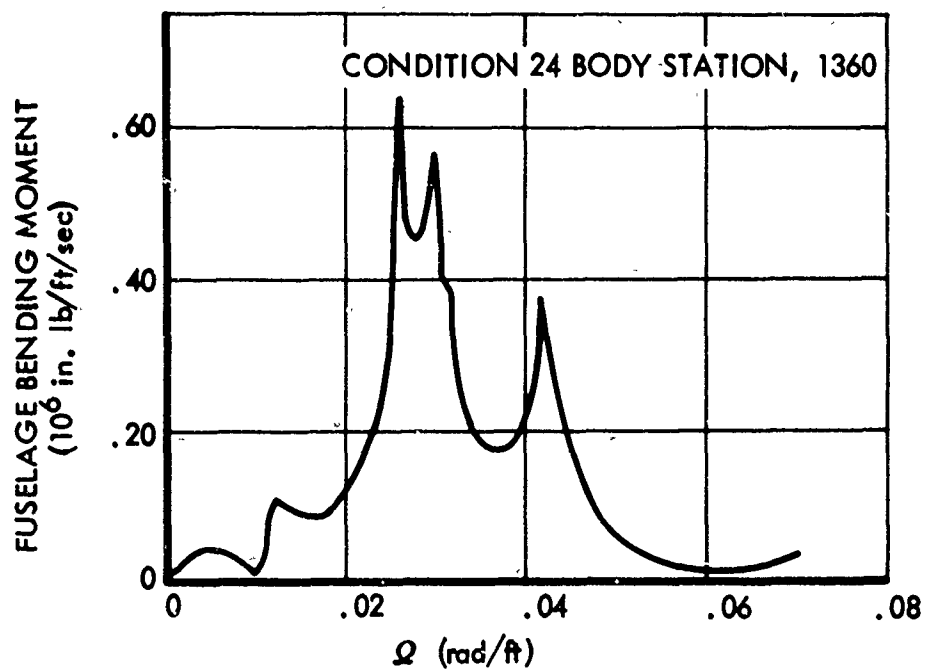


FIGURE 30d. FREQUENCY RESPONSE, FUSELAGE VERTICAL BENDING MOMENT

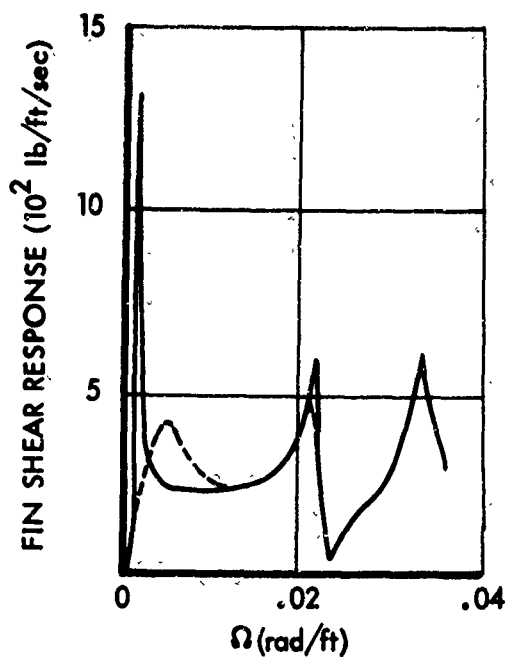


FIGURE 31a. FREQUENCY RESPONSE, FIN SHEAR

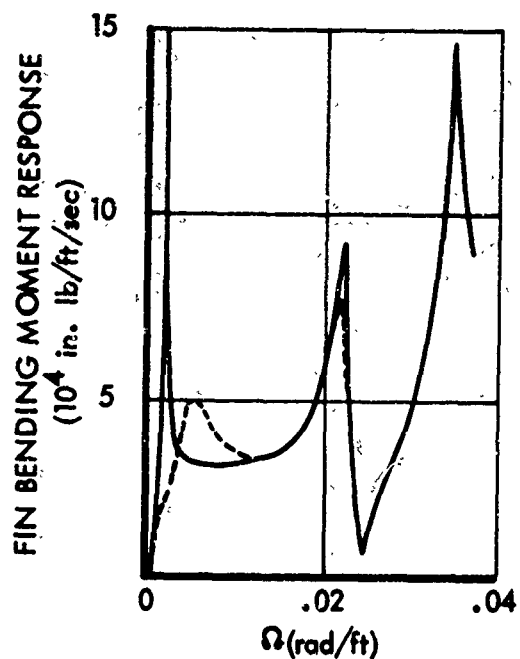


FIGURE 31b. FREQUENCY RESPONSE, FIN BENDING MOMENT

NOTE:

- YAW DAMPER ON
- YAW DAMPER OFF

CONDITION 10, 10 YD  
FIN ELASTIC AXIS  
STA. 67

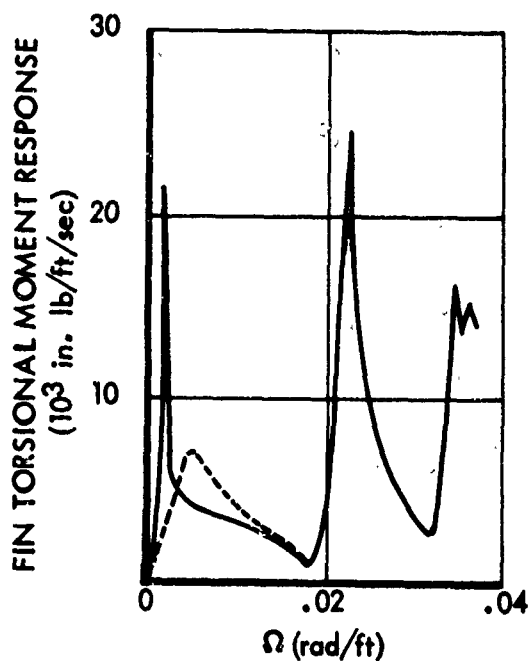


FIGURE 31c. FREQUENCY RESPONSE, FIN TORSION

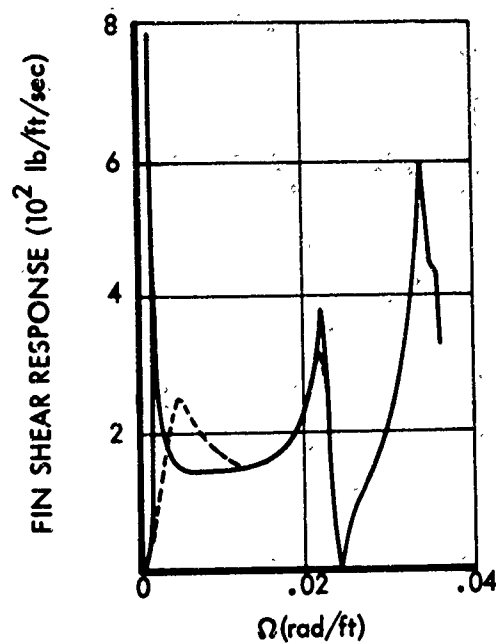


FIGURE 31d. FREQUENCY RESPONSE, FIN SHEAR

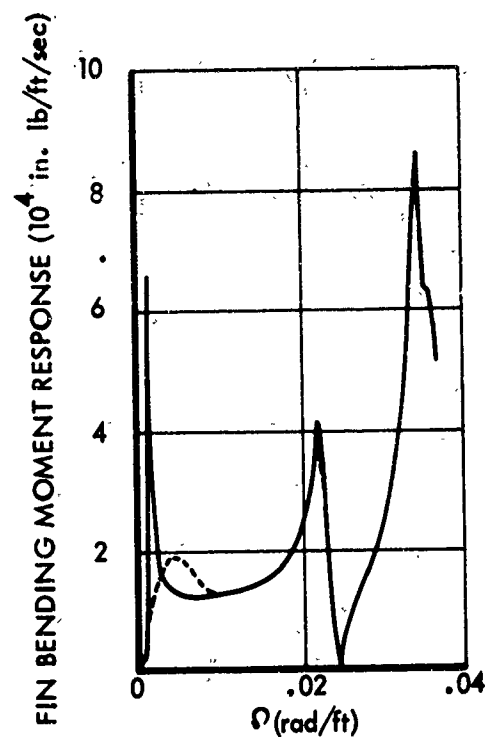


FIGURE 31e. FREQUENCY RESPONSE, FIN TORSION

NOTE  
 ----- YAW DAMPER ON  
 \_\_\_\_\_ YAW DAMPER OFF  
 CONDITION 10, 10 YD  
 FIN E.A. STA. 158

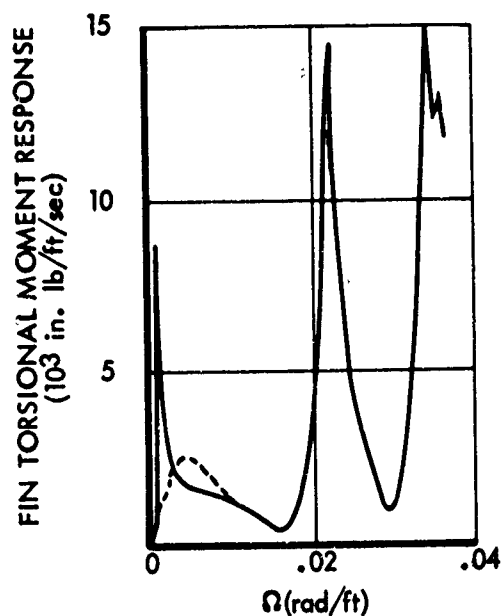


FIGURE 31f. FREQUENCY RESPONSE, FIN BENDING MOMENT



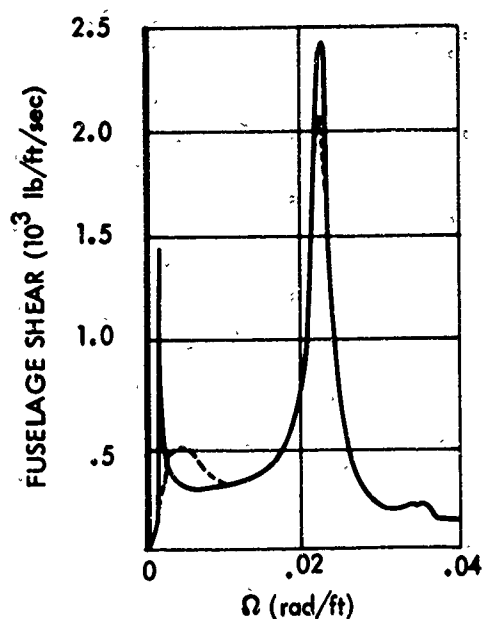


FIGURE 32a. FREQUENCY  
RESPONSE, FUSELAGE  
LATERAL SHEAR

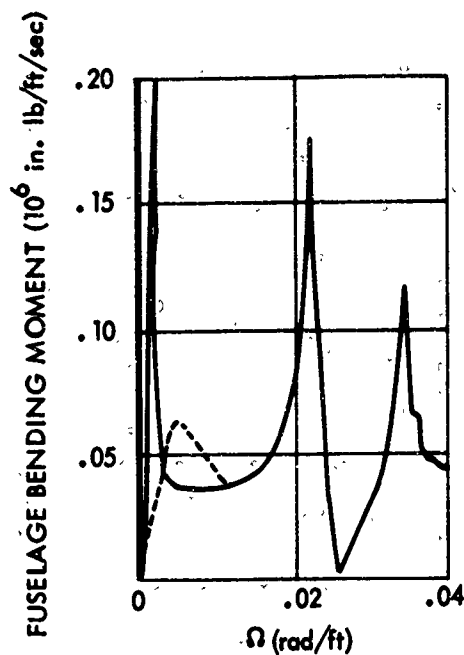


FIGURE 32b. FREQUENCY  
RESPONSE, FUSELAGE  
LATERAL BENDING MOMENT

NOTE  
 ----- YAW DAMPER ON  
 ————— YAW DAMPER OFF  
 CONDITION 10, 10 YD  
 BODY STATION 1375

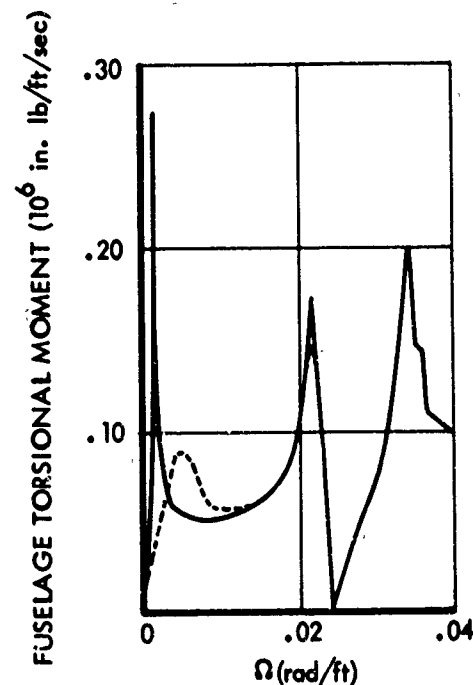


FIGURE 32c. FREQUENCY  
RESPONSE, FUSELAGE  
TORSIONAL MOMENT

The major response peaks for the wing loads result from airplane pitch and from the first and fifth flexible modes. This is reasonable, because the first and fifth flexible modes constitute the largest part of the coupled wing bending deflection. The wing torsion loads receive their major responses from the airplane pitch and first and fourth flexible modes, the fourth mode is primarily wing torsion. The second and third flexible modes are predominantly nacelle side bending modes; therefore, they contribute relatively little to the overall wing loads. The fuselage vertical bending moment and shear loads are derived mainly from the fifth flexible airplane mode, which is predominantly fuselage vertical bending.

The primary response for the vertical tail results from the Dutch roll mode; however, when the yaw damper is on the fin and aft body flexible modes become more important. The principal side bending moment, shear, and torsion at Body Balance Station 1360 again results from the Dutch roll response when the yaw damper is off. All of the frequency response functions shown in Figs. 27 through 32 are the modulus of the complex frequency responses. The load frequency response functions were multiplied by the gust power spectra which resulted in output load power spectra. The rms loads were obtained by taking the square root of the area under the load power spectra. Typical variations of the rms load for the wing, fuselage, and vertical tail are shown in Figs. 33, 34, 35 and 36, respectively.

#### Determination of Critical Flight Conditions and Critical Structure, Vertical Analyses

Initial efforts to arrive at design frequencies of exceedance using the mission profile concept and to arrive at values of  $\sigma_w \eta_d$  using the design envelope approach were based on limit allowable bending moments. The use of bending moments alone to estimate allowable limit strength is not exactly correct, because the limit design stresses result from combined loading; therefore, properly combined shear, moment, and torsion loads should be considered. Since the stresses in critical areas are more sensitive to bending moment, and reasonable assumptions are made as to the magnitude and phasing of the associated shear and torsion, it was assumed that the critical structural areas and the critical conditions could be established by a bending moment criteria.

Four weight conditions were analyzed in the vertical analyses for an altitude of 22,000 ft. at the design cruise speed of 375 kt. EAS. The resulting rms wing and body bending moments for a unit rms gust velocity were obtained and divided into the incremental limit allowable bending moments to give allowable values of  $\sigma_w \eta_d$ . These allowable  $\sigma_w \eta_d$  values are plotted in Fig. 37 versus fraction of wing semi-span and in Fig. 38 versus Body Balance Station. It will be noted from Fig. 37 that two

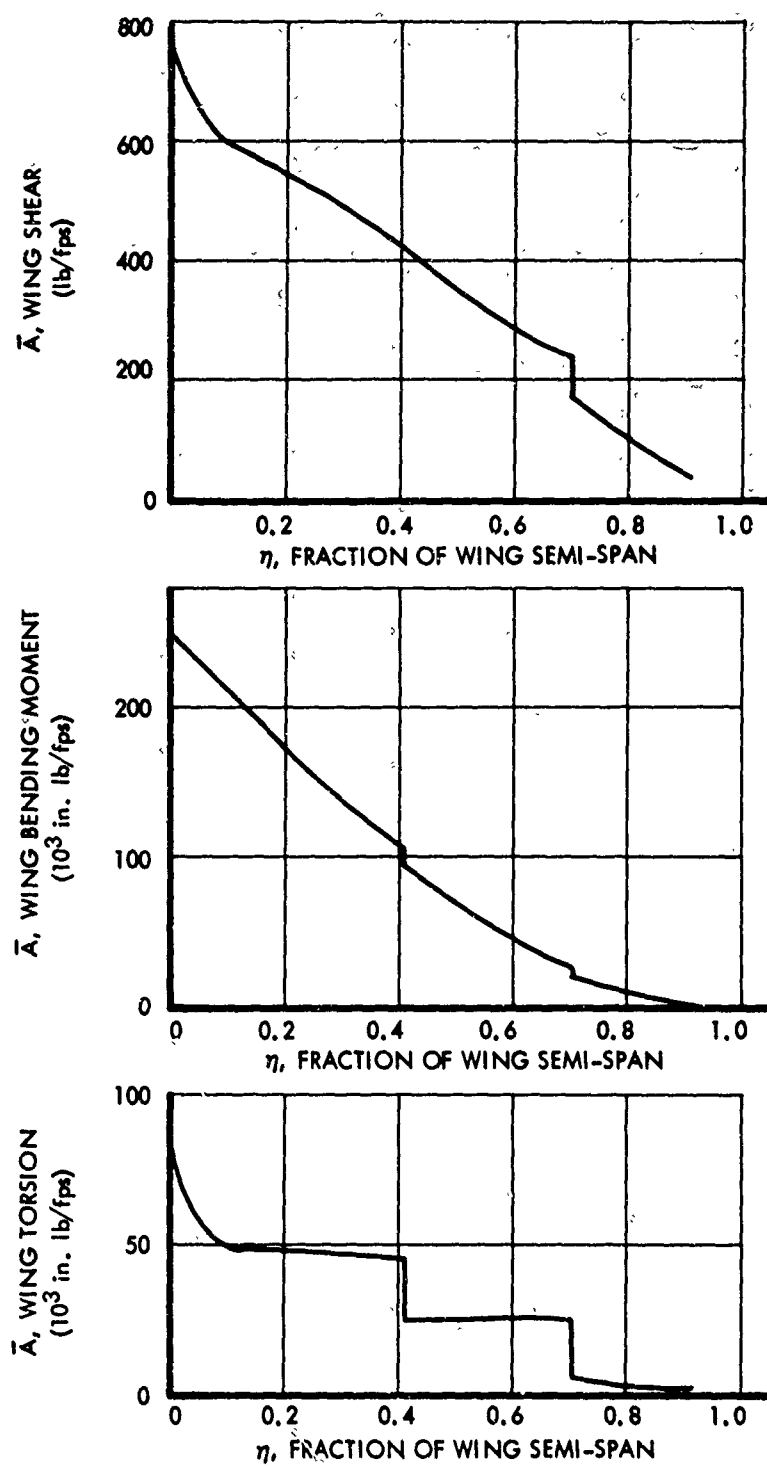


FIGURE 33. DISTRIBUTION OF RMS WING LOADS - CONDITION 24

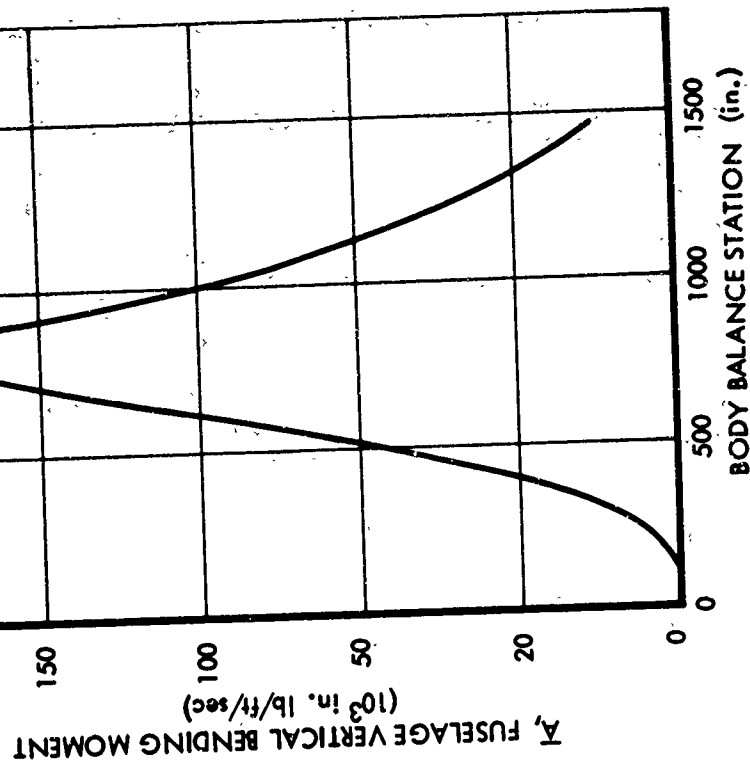
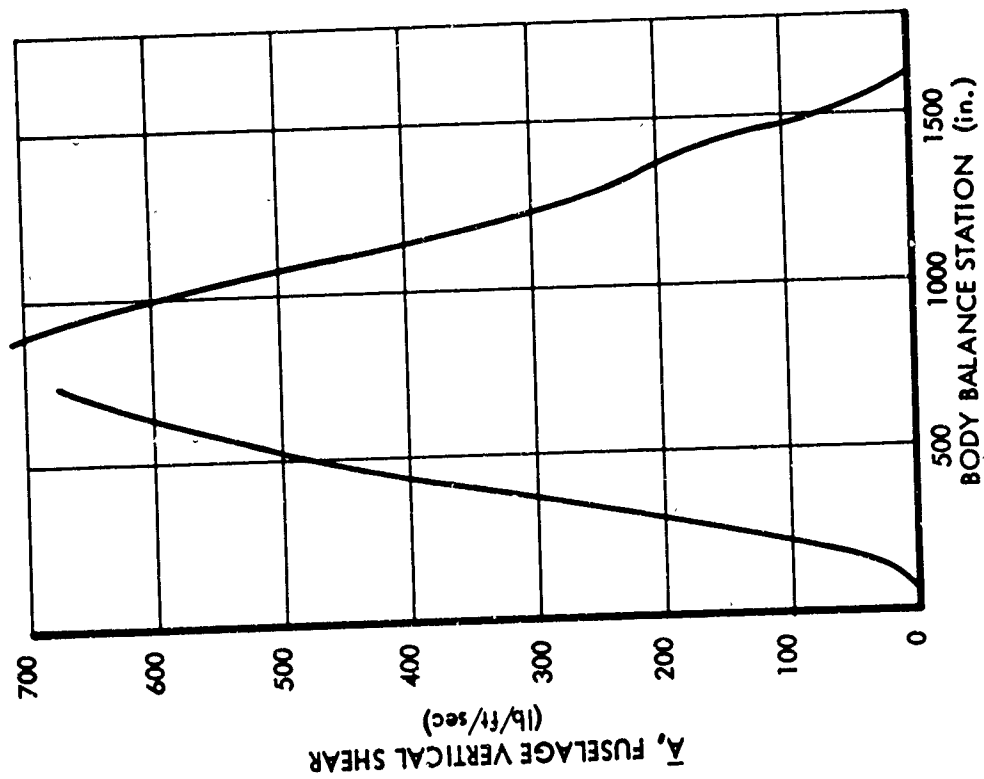


FIGURE 34. DISTRIBUTION OF RMS FUSELAGE LOADS,  
VERTICAL ANALYSIS - CONDITION 24

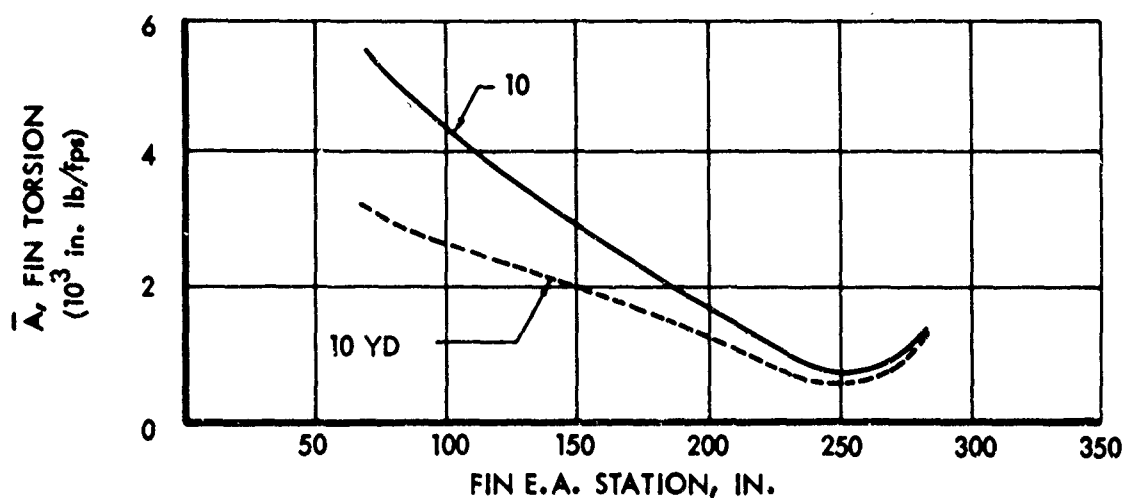
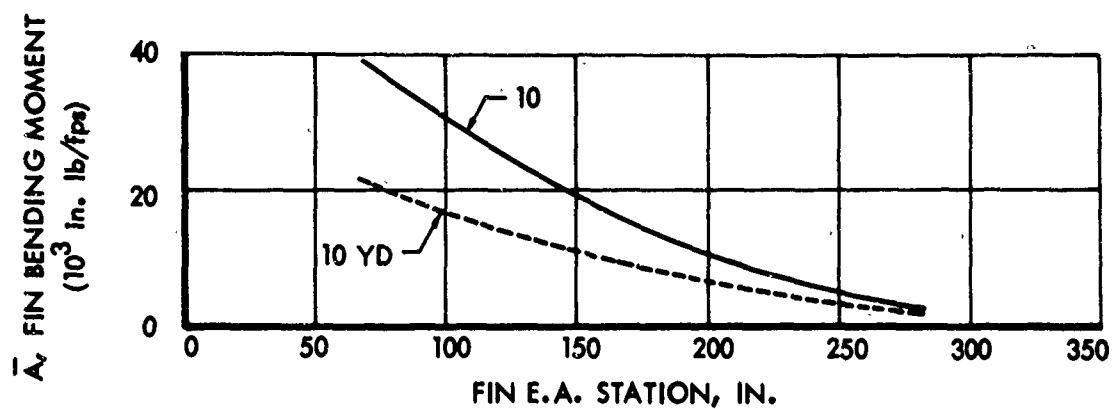
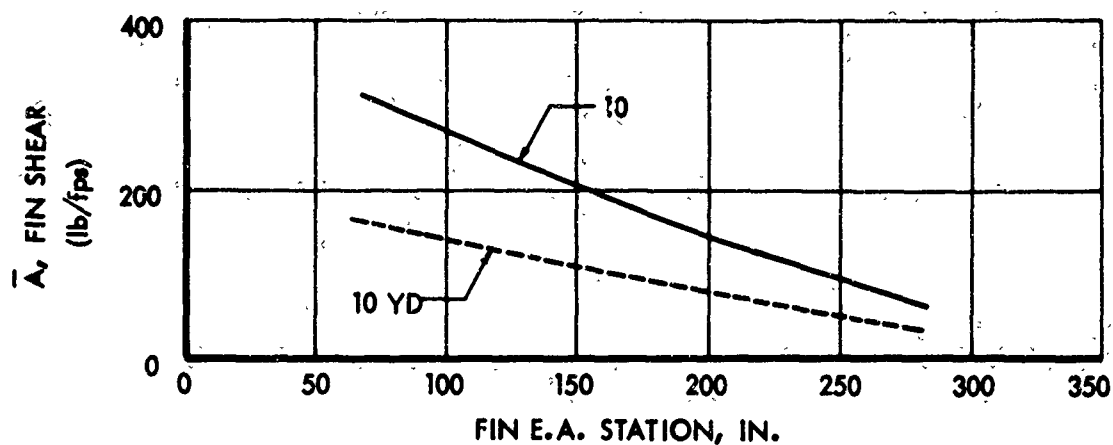


FIGURE 35. DISTRIBUTION OF RMS FIN LOADS - CONDITION 10, 10YD

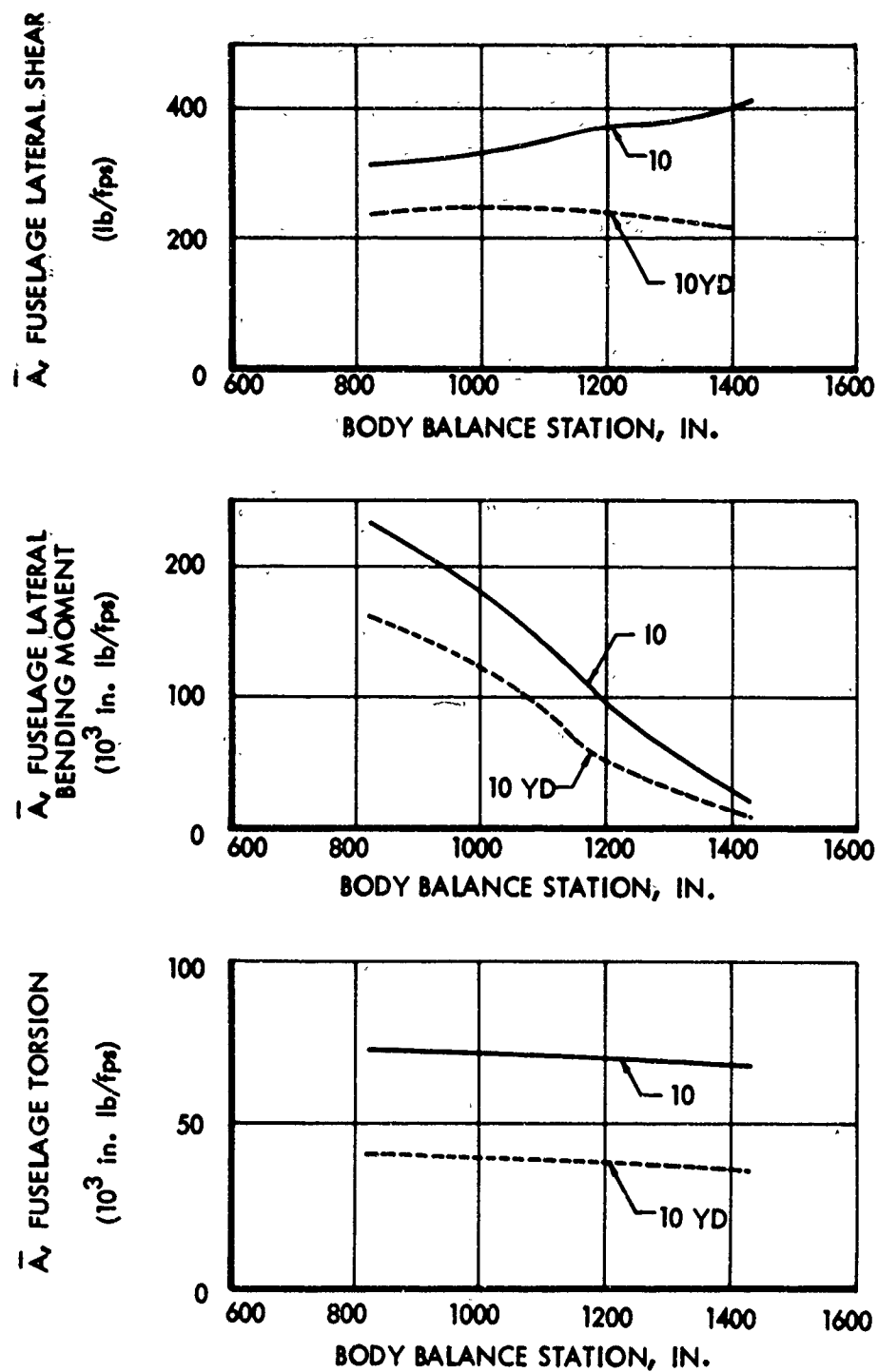


FIGURE 36. DISTRIBUTION OF RMS BODY LOADS, LATERAL ANALYSIS - CONDITION 10, 10YD

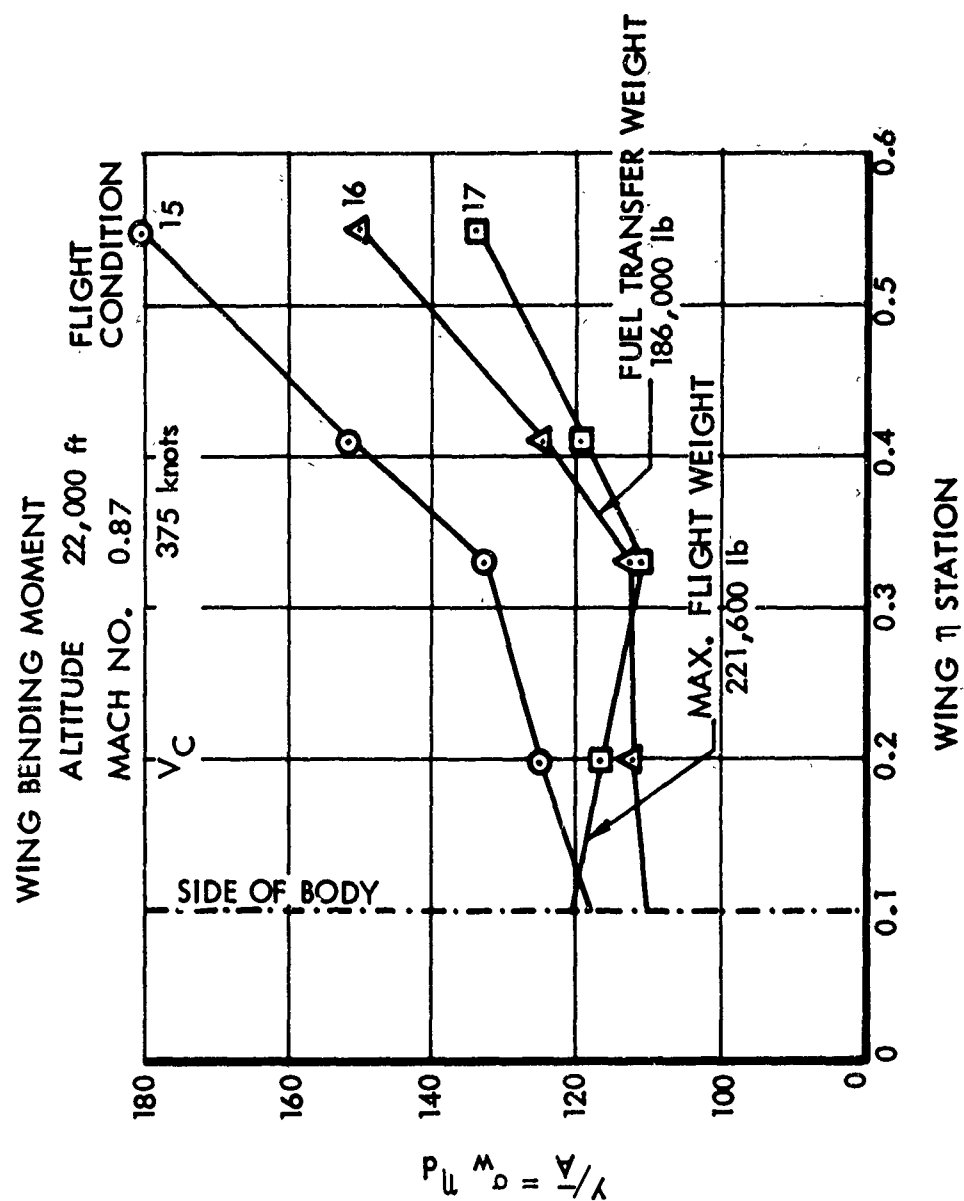


FIGURE 37. WING  $\sigma_v \eta_d$  BASED ON BENDING MOMENTS

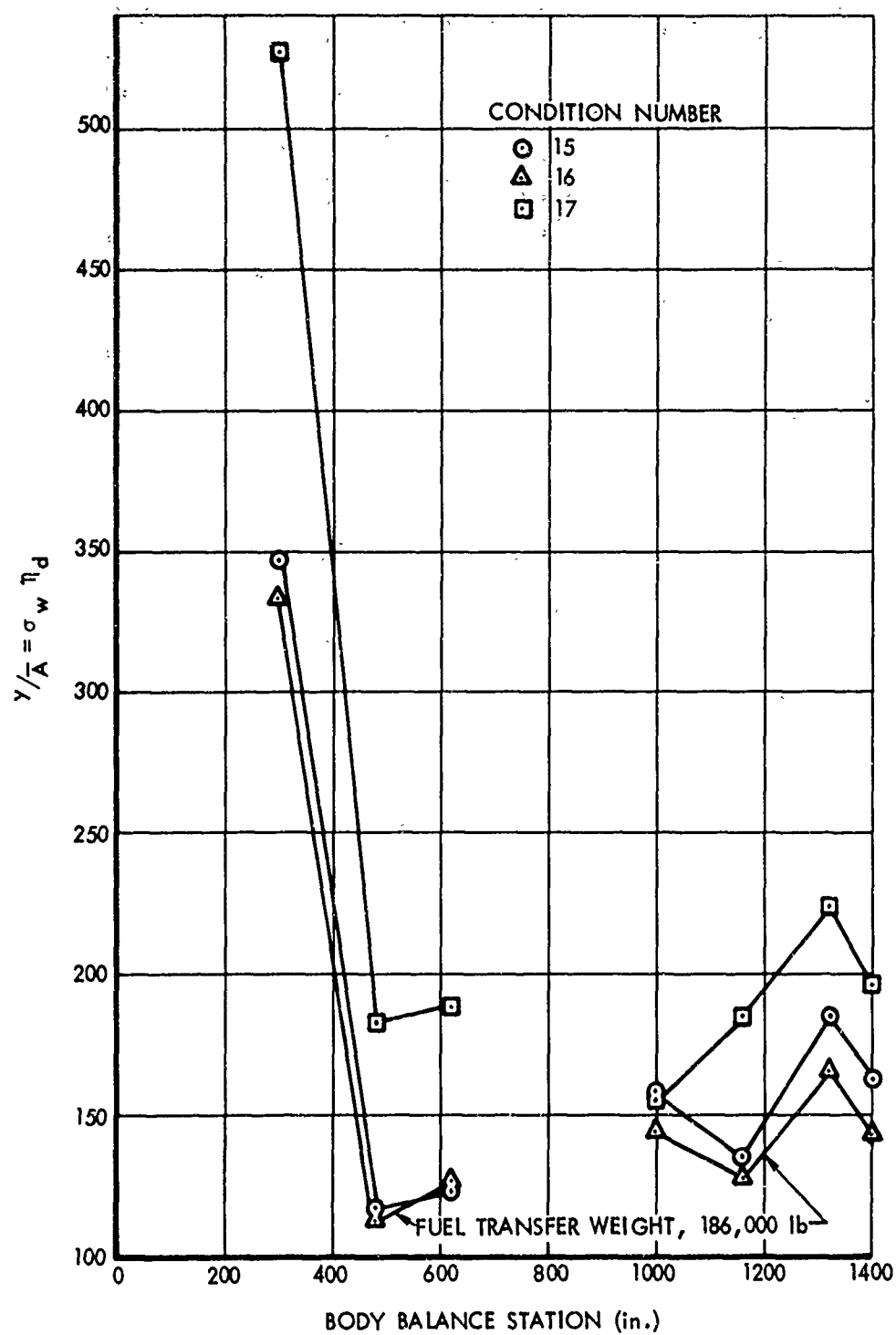


FIGURE 38. FUSELAGE  $\sigma_w \eta_d$  BASED ON VERTICAL BENDING MOMENT



weight conditions, the fuel transfer weight condition, 186,000 lb., and the maximum flight weight condition, 221,600 lb., appear to be equally critical inboard of 33 percent wing semi-span. Since neither condition was clearly critical, both weight conditions were further examined for flight altitudes of 5,000, 15,000, 30,000, and 40,000 ft. The results of these altitude variations are given in Fig. 39, wherein values of  $\bar{A}$  are plotted for wing bending moment at Wing Eta Stations .12 and .33. The corresponding altitude variations of the one factor aeroelastic loads are given in Fig. 40. The altitude conditions were analyzed at design cruise velocity,  $V_C$ ; thus, the true airspeed and Mach number increased with altitude until the design cruise Mach number was reached. Above this altitude the true airspeed decreases for a constant design Mach number up to 35,000 ft. Above 35,000 ft. the true airspeed remains constant with increasing altitude. The effect of this variation of true airspeed is apparent in the altitude trends for the rms and one factor flight bending moments.

Values for  $\sigma_w \eta_d$  were calculated for each of the two weight configurations mentioned previously for various altitudes. This information is shown in Fig. 41. The discontinuities in the curves reflect the abrupt change in cruise velocity at 24,000 ft. The preliminary boundary of minimum  $\sigma_w \eta_d$  is defined by Conditions 26, 27, 17, 28 and 21 at 5,000, 15,000, 22,000, 30,000 and 40,000 ft., respectively.

Speed variations to further define the boundary of minimum  $\sigma_w \eta_d$  were examined for altitudes of 15,000 and 22,000 ft. The velocities chosen were the gust penetration speed,  $V_B$ , 253 kt. EAS; an average cruise speed, 300 kt. EAS, and the design dive speed,  $V_D$ , 445 kt. EAS or  $M_D$ , .95. The fuel transfer weight condition was chosen for the 22,000 ft. speed variation, and the maximum flight weight was chosen for the 15,000 ft. variation. These conditions were deemed to be the most critical for the respective altitudes. The results of the speed variations are given in Figs. 42 and 43. The most critical speed for the 15,000 ft. altitude, maximum flight weight condition, appeared to be very near the design cruise speed,  $V_C$ , 375 kt. EAS or 472 kt. TAS; however, at 22,000 ft. the critical speed was found to be less than  $V_C$ . One additional condition was analyzed for 22,000 ft. to pinpoint the critical speed at 340 kt. EAS or 480 kt. TAS. Finally, center of gravity variations were studied for this condition, and the minimum  $\sigma_w \eta_d$  values were obtained for a cg location at .25 MAC, Condition 24C. The resulting boundary of minimum  $\sigma_w \eta_d$  is presented on Fig. 44. As can be determined from this figure, the most critical or least value of  $\sigma_w \eta_d$  for Flight Condition 24C, Wing Eta Station .33 is 108.3.

Minimum values of  $\sigma_w \eta_d$  for the fuselage were obtained by observing the variation of rms fuselage bending moments with altitude and speed. The forward fuselage appeared to be more critical than the aft fuselage. The one factor loads for the forward body remained nearly the same for

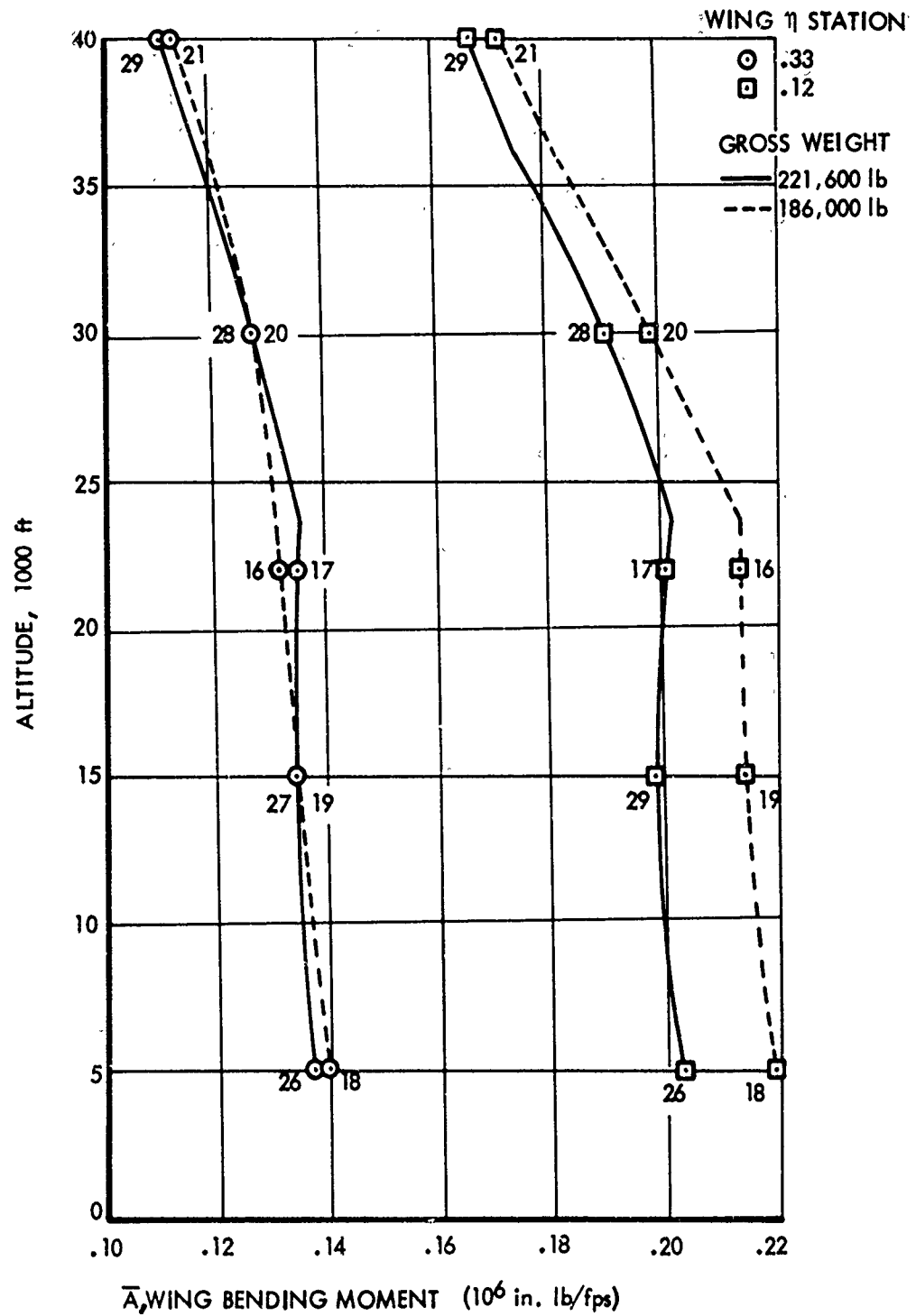


FIGURE 39. VARIATION OF RMS WING BENDING MOMENTS WITH ALTITUDE

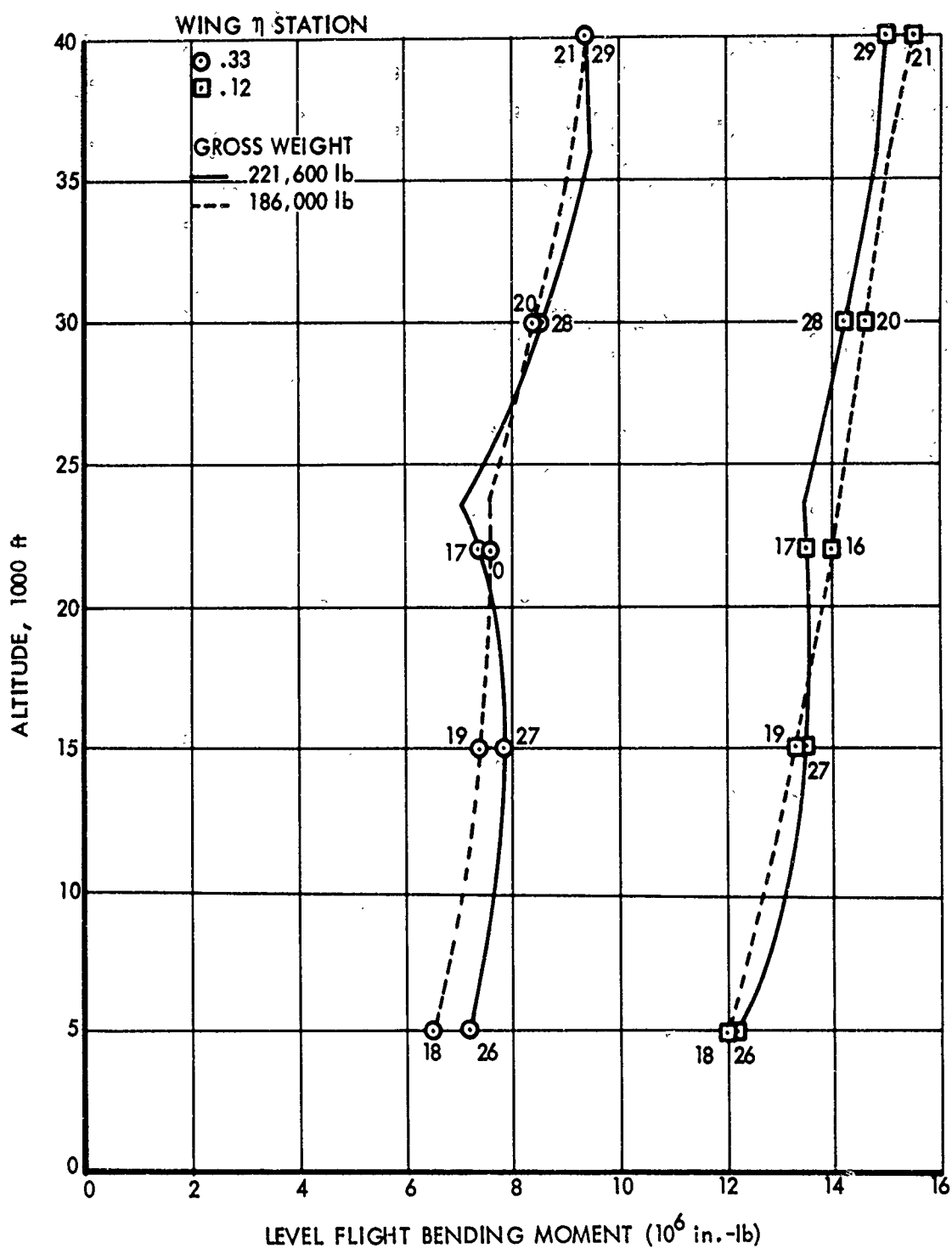


FIGURE 40. VARIATION OF LEVEL FLIGHT WING BENDING MOMENTS WITH ALTITUDE

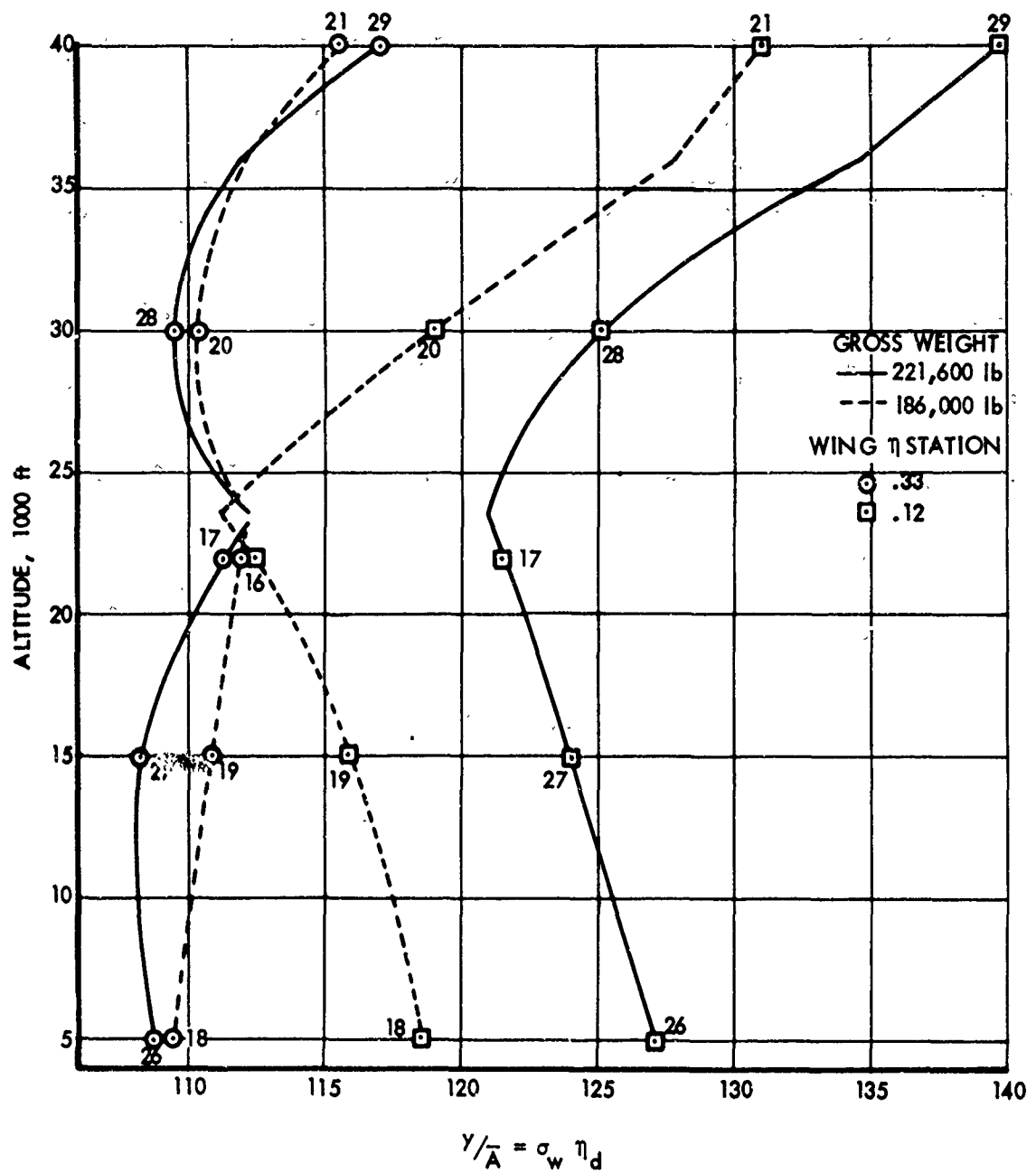


FIGURE 41. VARIATION OF WING BENDING MOMENT  $\sigma_w \eta_d$  WITH ALTITUDE

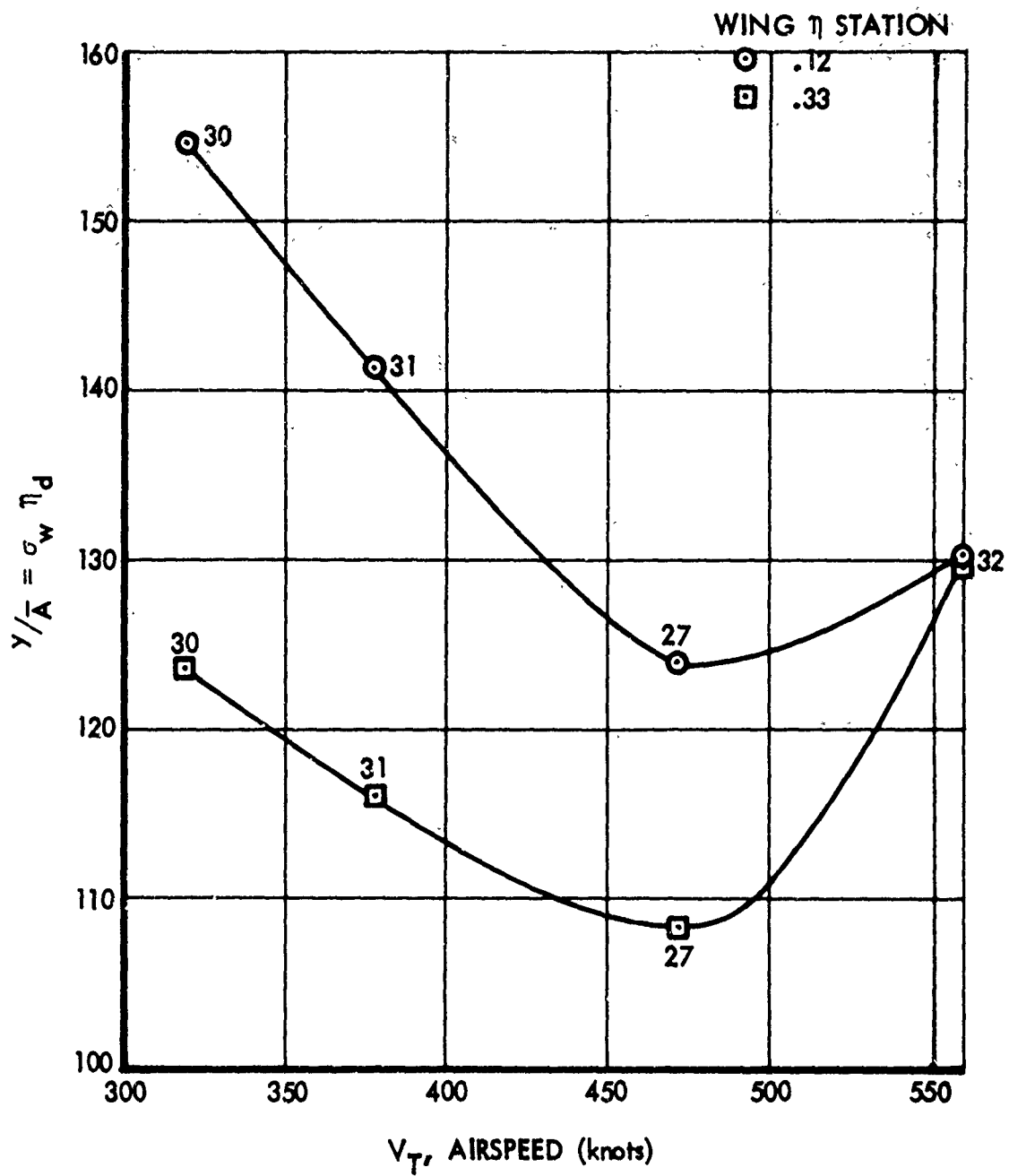


FIGURE 42. EFFECT OF SPEED ON WING BENDING MOMENT  
 $\sigma_w \eta_d$  15,000 FT. ALTITUDE

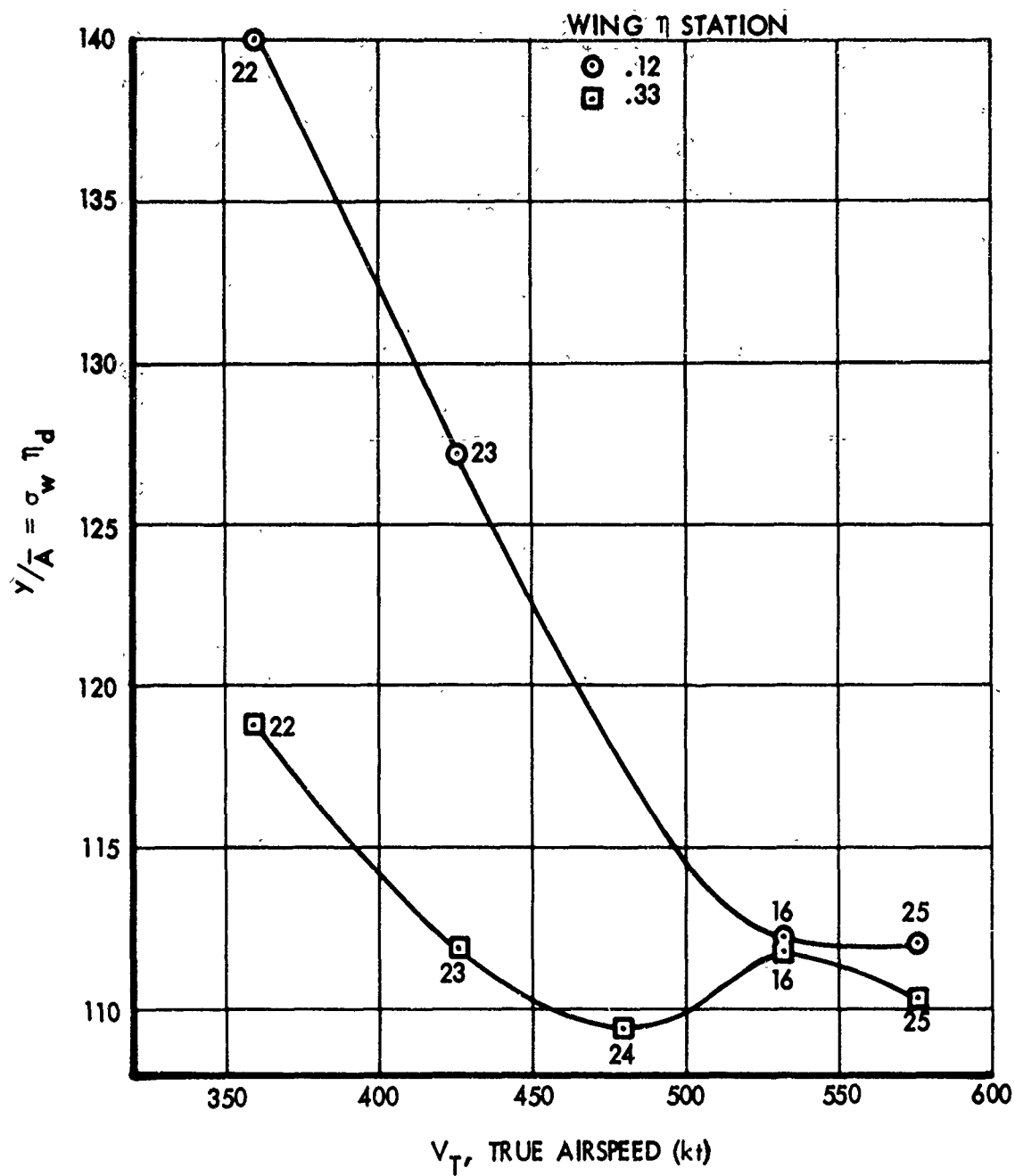


FIGURE 43. EFFECT OF SPEED ON WING BENDING MOMENT  
 $\sigma_w \eta_d$ , 22,000 FT. ALTITUDE

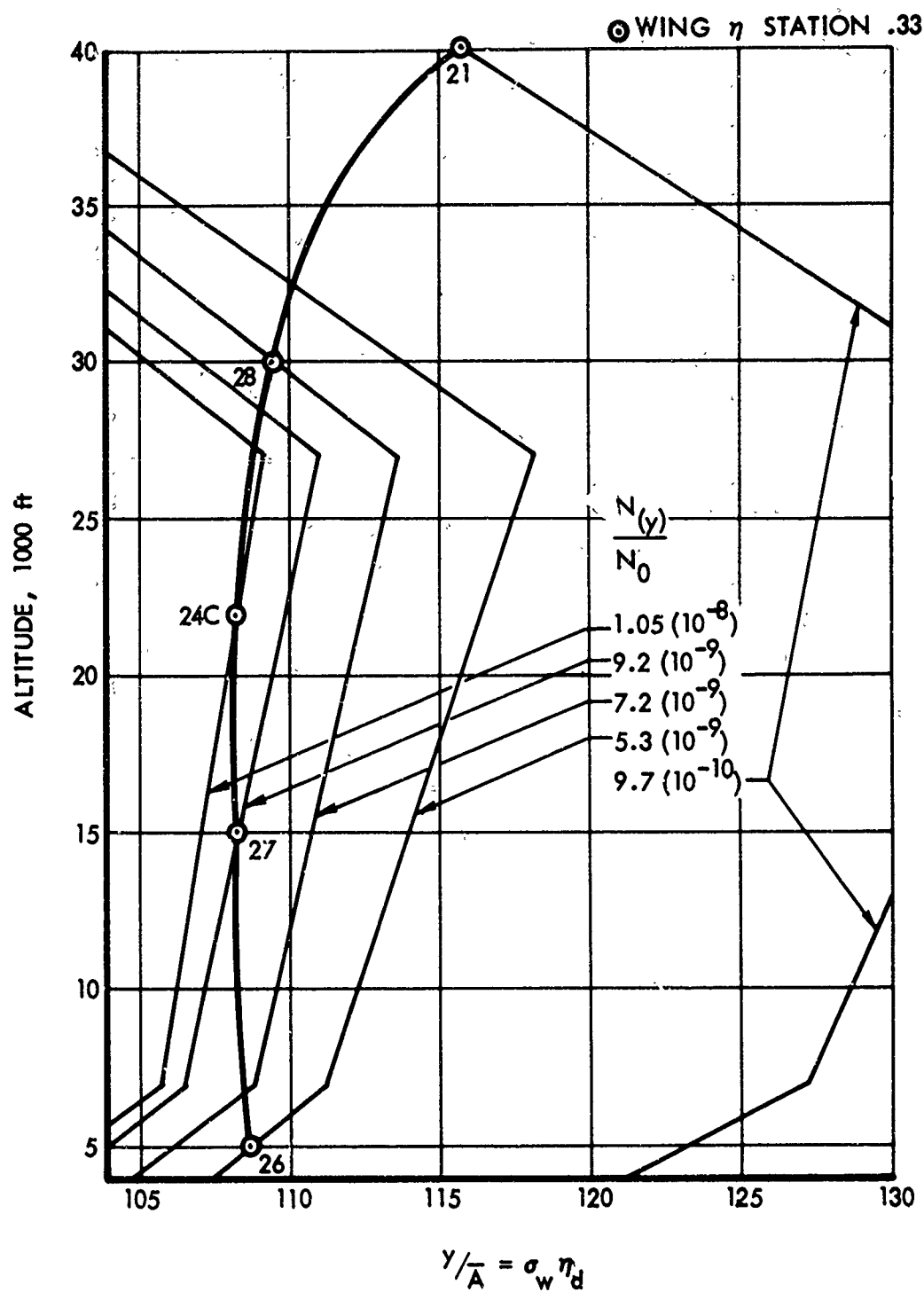


FIGURE 44. VARIATION OF MINIMUM WING BENDING MOMENT  $\sigma_w \eta_d$  WITH ALTITUDE

all gross weight conditions; therefore, the variation in  $\sigma_w \eta_d$  was largely a function of the incremental bending moments. The variation of fuselage  $\bar{A}$  values with altitude at design cruise velocity is given in Fig. 45(a). The effect of speed variations on the rms bending moments at 22,000 ft. is given in Fig. 45(b). Representing these variation as  $\sigma_w \eta_d$  in Fig. 46, it was concluded that the vertical gust loading on the fuselage was most critical at Body Balance Station 480,\* for Flight Condition 16. The minimum value of  $\sigma_w \eta_d$  for this body station was 112.2.

The average number of exceedances per hour of limit vertical bending moment were calculated for the wing for Wing Eta Stations .12 and .33 and for the fuselage for Body Balance Stations 480\* and 1160. These results, shown in Figs. 47 and 48 respectively, were based on the flight profiles describing the average airplane usage described in Analyses Conditions. The design frequency of exceedance for the wing was determined as  $3.7(10)^{-6}$  exceedances per hour. The corresponding design exceedance level for the fuselage is  $3.3(10)^{-7}$  exceedances per hour. It will be observed that the highest or most critical frequency of exceedance occurs at Wing Eta Station .33, the same station that showed the minimum  $\sigma_w \eta_d$ . The highest frequency of exceedance for the body also occurs at the same body balance station that gave the minimum  $\sigma_w \eta_d$  for the fuselage, Body Balance Station 480. Therefore, it appears that these two rather different approaches are consistent in arriving at the most critical stations based on the bending moment criteria. A comparison of the mission profile and design envelope frequencies of exceedance of wing limit strength may be of interest. By examining Fig. 44 herein, it is seen that the critical  $\sigma_w \eta_d$  occurs in the altitude range 22,000 to 27,000 ft., and corresponds to an  $N(y)/N_0$  value of  $1.1 \times 10^{-8}$ . For the critical condition the bending moment zero crossings are 1.20 per sec., which gives the following  $N(y)$  value:

$$(1.1 \times 10^{-8}) (1.20) (3600) = 4.8 \times 10^{-5} \text{ exceedances per hour}$$

As shown in Fig. 47, the frequency of exceedance value as calculated by the flight profile analysis is  $3.7 \times 10^{-6}$ . The ratio of design envelope to flight profile frequency of exceedance at the limit strength level, is therefore

$$\frac{4.8 \times 10^{-5}}{3.7 \times 10^{-6}} = 13.0$$

To extend the comparison to a load basis let us suppose that the flight profile frequency of exceedance were to be applied on a design envelope

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\*This corresponds to Body Station 540 (See Fig. 23)



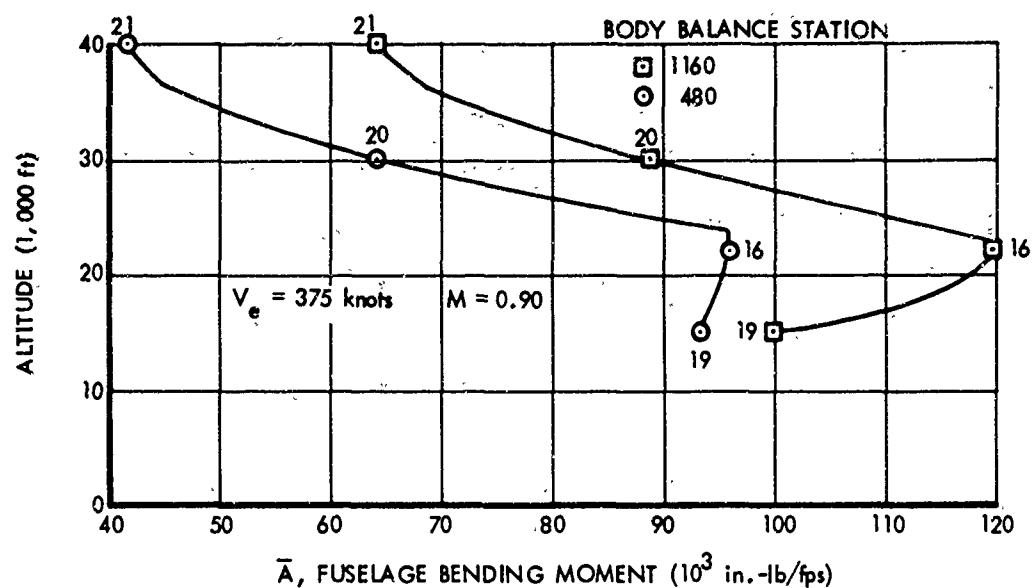


FIGURE 45. (a) VARIATION OF FUSELAGE RMS VERTICAL BENDING MOMENTS WITH ALTITUDE

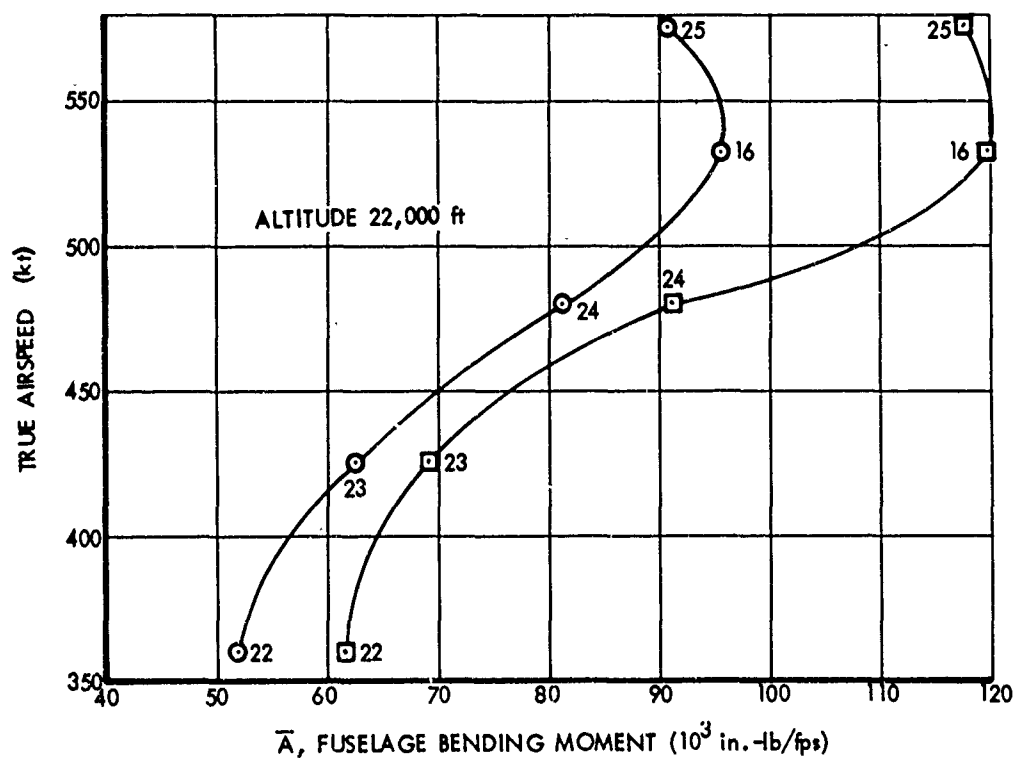


FIGURE 45. (b) VARIATION OF FUSELAGE RMS VERTICAL BENDING MOMENTS WITH SPEED

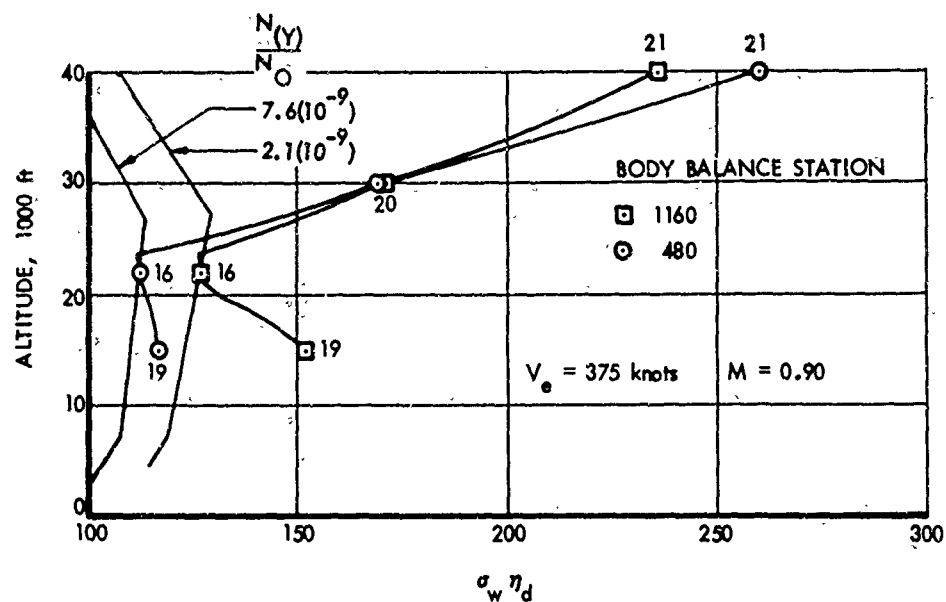


FIGURE 46. (a) VARIATION OF ALLOWABLE FUSELAGE  $\sigma_w \eta_d$  WITH ALTITUDE BASED ON VERTICAL BENDING MOMENTS

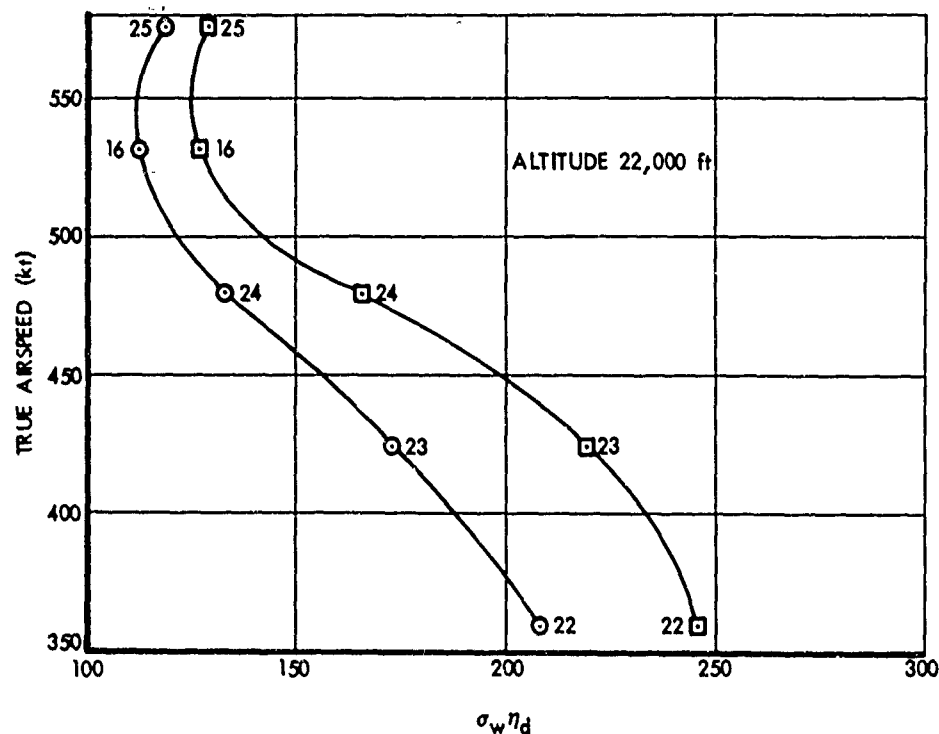


FIGURE 46. (b) VARIATION OF ALLOWABLE FUSELAGE  $\sigma_w \eta_d$  WITH SPEED BASED ON VERTICAL BENDING MOMENTS

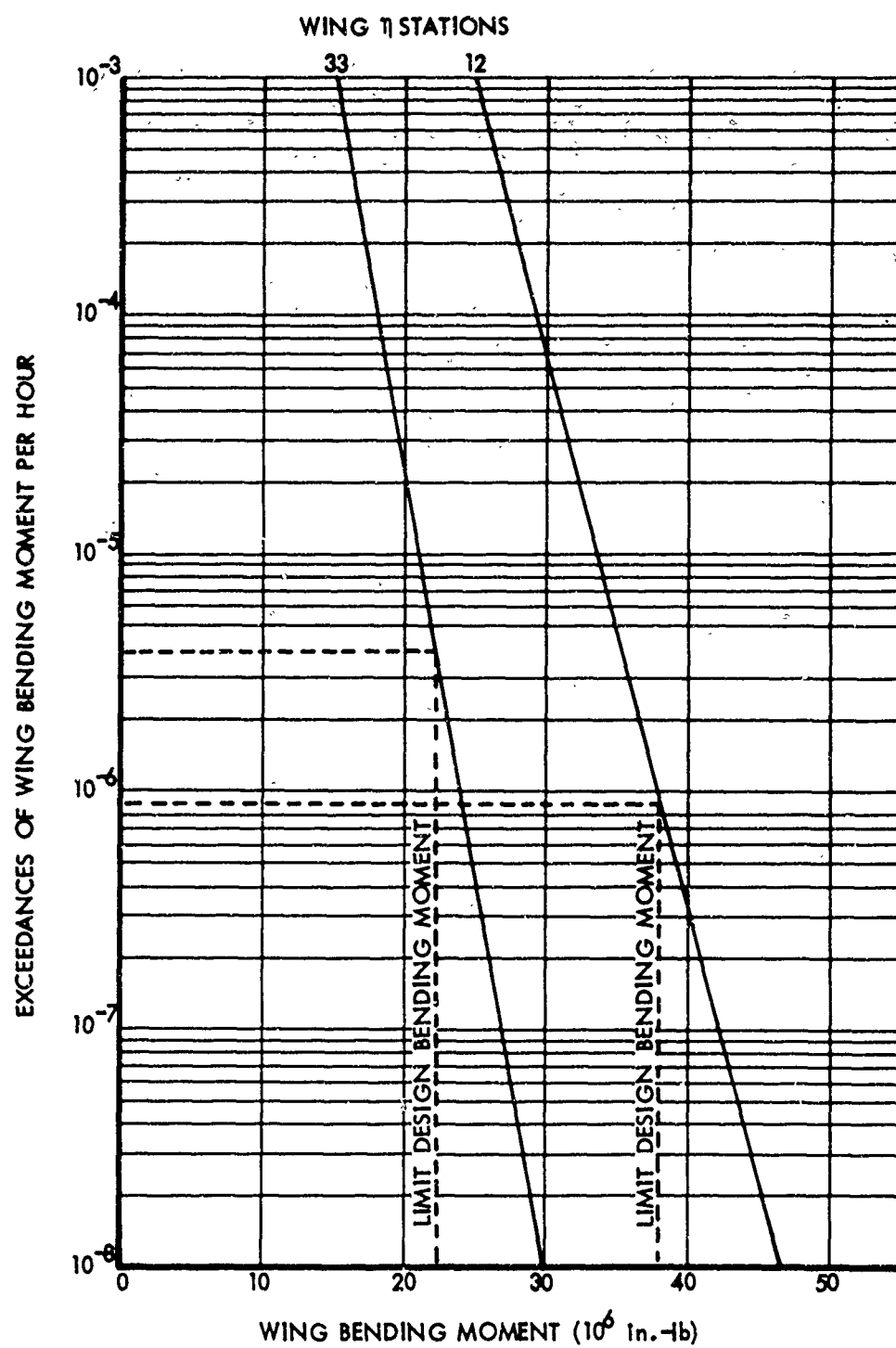


FIGURE 47. EXCEEDANCES OF WING BENDING MOMENT,  
WING  $\eta$  STATION .33

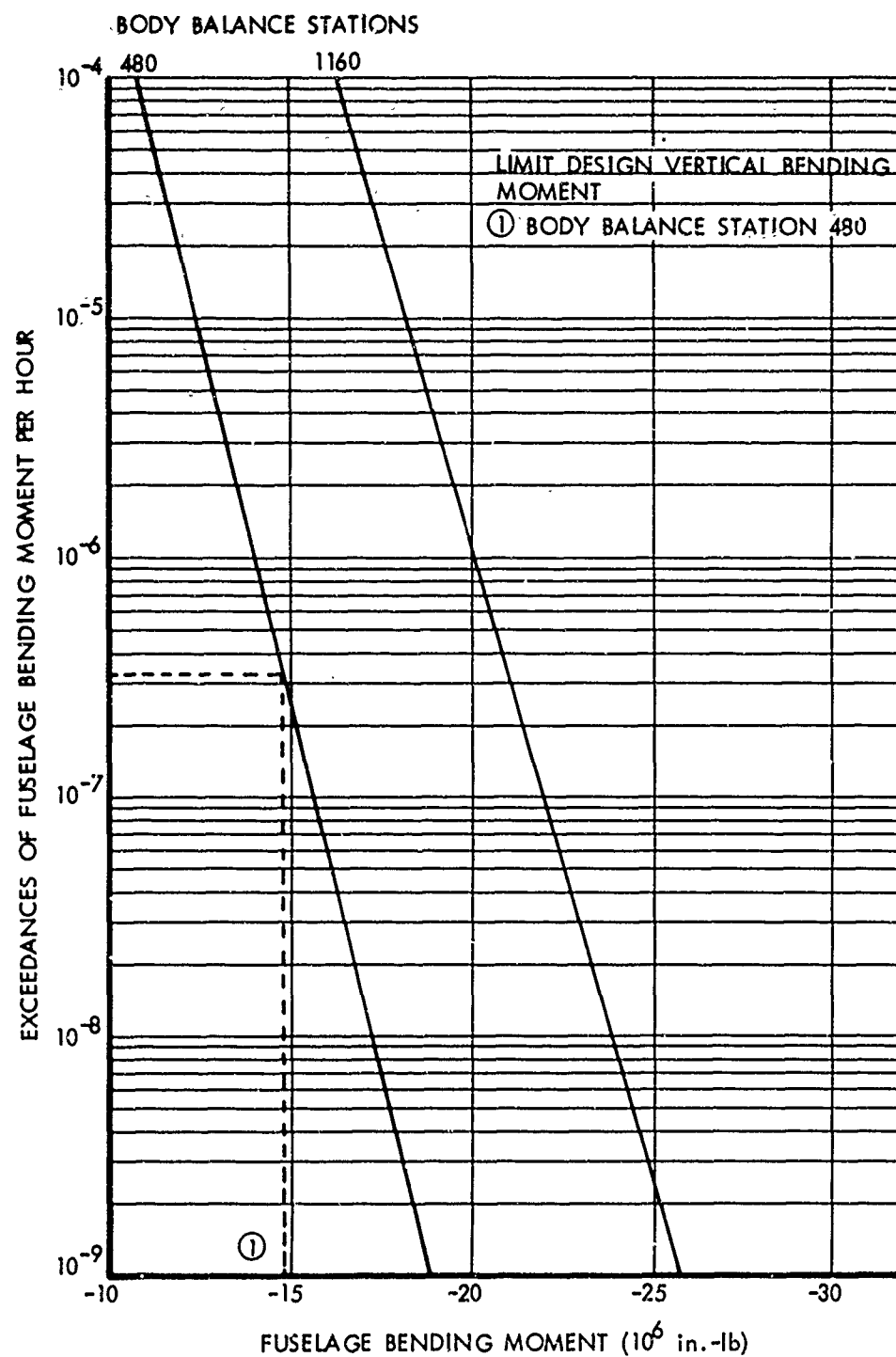


FIGURE 48. EXCEEDANCES OF FUSELAGE VERTICAL BENDING MOMENT, BODY BALANCE STATIONS 480, 1160

basis - for example, in order to provide for operation of the airplane 100% of the time at its most critical flight condition. The  $N(y)/N_0$  value for the critical design envelope condition using the flight profile  $N(y)$  with the design envelope  $N_0$  is:

$$\frac{N(y)}{N_0} = (3.7 \times 10^{-6}) \left(\frac{1}{1.20}\right) \left(\frac{1}{3600}\right) = 8.6 \times 10^{-10}$$

At an altitude of 22,000 ft., the corresponding  $\sigma_w \eta_d$ , from Fig. 47 is 138 ft. per sec. But strength has been provided only for  $\sigma_w \eta_d = 108.3$  ft. per sec. As a result, the incremental loads would have to be increased in the ratio  $138/108.3 = 1.27$ . The corresponding ratio of increase of net loads, assuming a one-factor bending moment of  $8.00 \times 10^6$  in.lb. and a limit allowable bending moment of  $22.25 \times 10^6$  in.lb., is

$$\frac{(22.25 - 8.00)(1.27) + 8.00}{22.25} = 1.17$$

#### Determination of Critical Flight Conditions and Critical Structure, Lateral Analyses

Previous lateral analyses of 707/720 type airplanes have indicated that the magnitudes of the gust loads for flight in continuous turbulence is largely dependent on the Dutch roll stability of the airplane. Naturally, the loads are influenced by the damping in the Dutch roll mode, and can reach large amplitudes as the damping decreases. There are regions within the flight regime where the Dutch roll damping decreases to the extent that the Dutch roll response would reach significant amplitudes if the controls were locked. However, the pilot would apply corrective control inputs either manually or automatically through the yaw damper system before such a situation would develop. Since this corrective action is at the discretion of the pilot, it is beyond the scope of this study to establish a threshold for corrective control.

Therefore, the lateral analyses for the design envelope approach were conducted for flight conditions defined by the design cruise velocity,  $V_C$ , at a variety of altitudes. An airplane configuration was chosen to give the greatest Dutch roll response. This configuration exhibits the maximum airplane yaw inertia, a high gross weight and a large yaw-roll product of inertia, all of which are associated with reduced Dutch roll stability. The rms fin and aft fuselage bending moments were divided into the limit allowable bending moments for the fin and aft fuselage, respectively, to give values of  $\sigma_v \eta_d$ . These  $\sigma_v \eta_d$  values were plotted against Fin Elastic Axis Station and Body Balance Station, and are shown in Figs. 49 and 50. The minimum value of  $\sigma_v \eta_d$ , 61.9, for the fin occurs at Fin Elastic Axis Station 158. The most critical aft body balance

ALT. 23,500 FT.

MACH NO. 0.90

$V_c$  374 KTS.

FLIGHT CONDITION 4b

○ YAW DAMPER OFF

□ YAW DAMPER ON

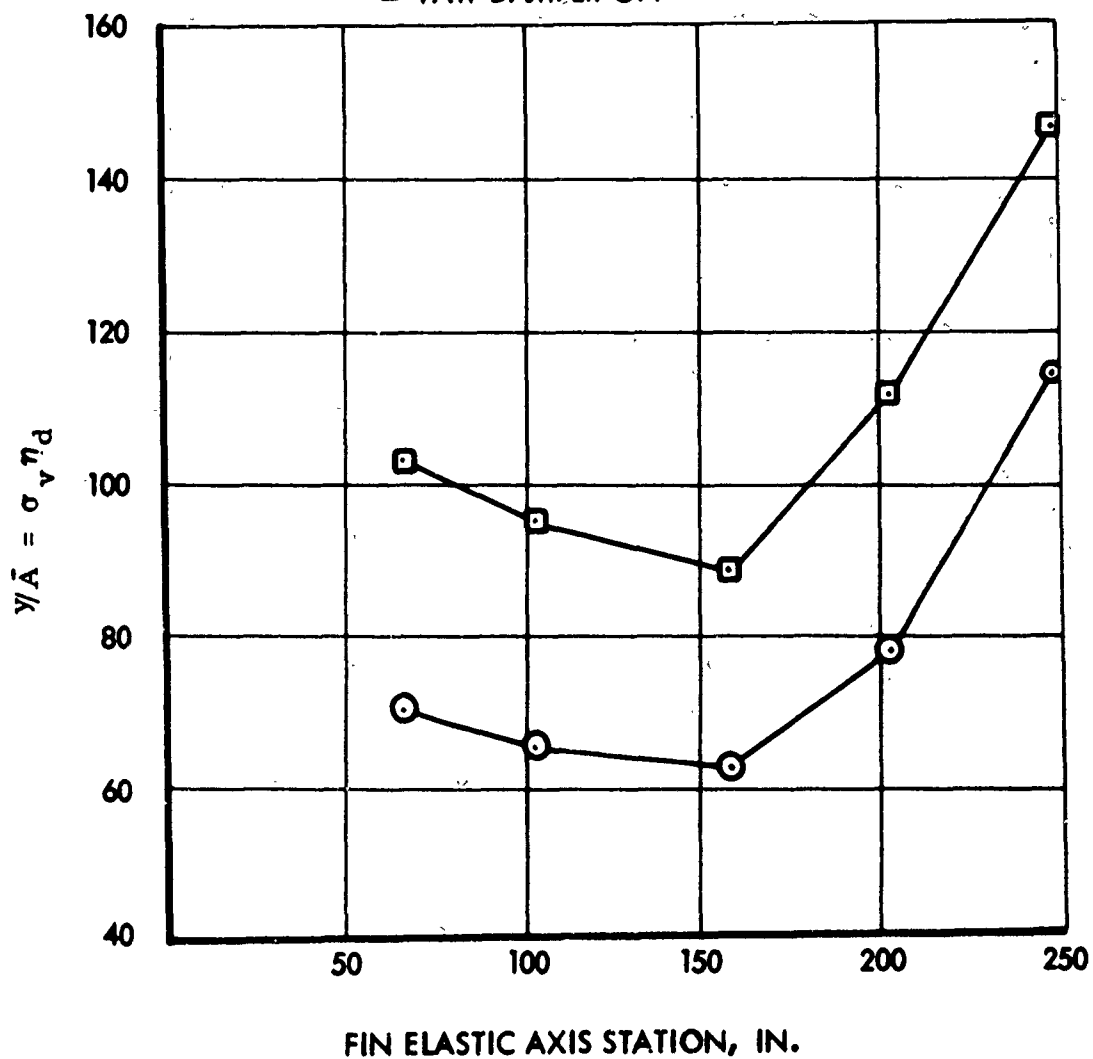


FIGURE 49. FIN  $\sigma_v \eta_d$  BASED ON BENDING MOMENTS

AFT FUSELAGE SIDE BENDING MOMENT  
CONDITION 4b

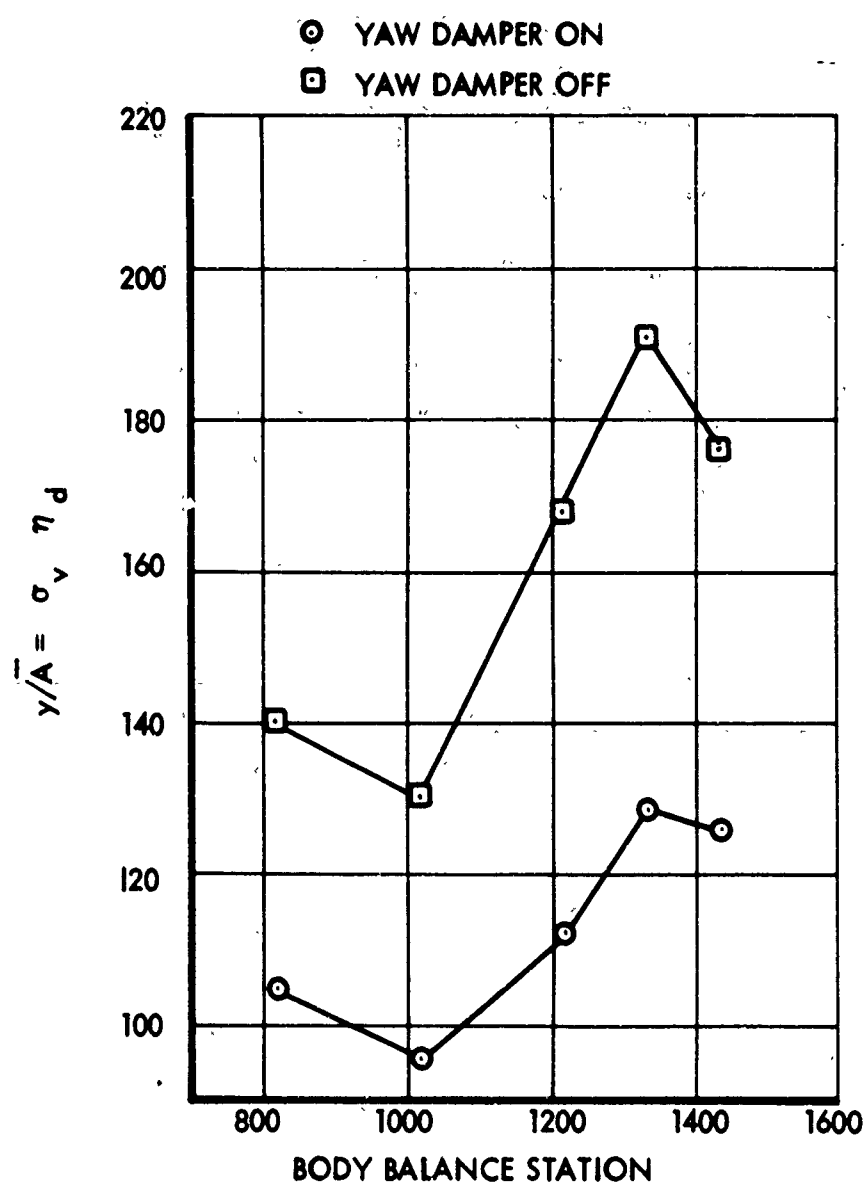


FIGURE 50. BODY  $\sigma_v \eta_d$  BASED ON AFT FUSELAGE SIDE BENDING MOMENTS - CONDITION 4b

station is 1080 where the  $\sigma_v \eta_d$  value was 94.3. The critical aft fuselage station from the lateral analysis standpoint is very nearly the same as critical aft fuselage station determined from the vertical analyses. Resultant values of  $\sigma_v \eta_d$  obtained for other altitude points on the design cruise speed envelope are shown in Figs. 51 and 52. The critical altitude for both the aft fuselage and fin is 23,500 ft. All of the above analyses conditions were repeated with the electronic yaw damper engaged. It will be noted from the results shown in Figs. 51 and 52 that the yaw damper is very effective in reducing the peak amplitude of the Dutch roll response, and therefore provides a large reduction, approximately 40 to 60 percent, in the fin and fuselage loads. The degree to which the yaw damper is effective in reducing the loads is largely dependent upon the effective Dutch roll damping it can provide.

The number of exceedances of limit design bending moment per average flight hour were calculated for the vertical tail Elastic Axis Stations 67 and 158 and Aft Fuselage Balance Stations 1020 and 1335. These values, obtained both with the yaw damper engaged and disengaged, are shown in Figs. 53, 54, 55, and 56. The most critical design value for the vertical tail,  $1.05(10)^{-4}$  exceedances per hour, occurs at Elastic Axis Station 158 with the yaw damper disengaged. When the yaw damper is operating full time the value is increased to  $4.0(10)^{-6}$  exceedances per hour, thus showing the capability of yaw damper system to reduce the level of the lateral dynamic loads. The design frequency of exceedance for the aft fuselage occurs at Body Balance Station 1020 and with the yaw damper disengaged is  $2.0(10)^{-7}$  exceedances per hour. The corresponding values with the yaw damper engaged is  $1.50(10)^{-9}$  exceedances per hour.

The critical or design values of  $\sigma_v \eta_d$  based on bending moment from the lateral analyses occur at the same vertical tail station and aft body station as the critical design frequency of exceedance obtained by the flight profile approach.

A summary of the exceedances of limit design load, as obtained from the Flight Profile Analyses using the bending moment criteria, are given in Fig. 57. Also shown in this figure, expressed as exceedance ratios, are

the design values of  $\frac{N(\sigma_w \eta_d)}{N_0}$  and  $\frac{N(\sigma_v \eta_d)}{N_0}$  as determined from the Design Envelope Analyses.

#### Results - Incremental CG Acceleration

The rms values,  $\bar{A}$ , of incremental center of gravity acceleration due to unit rms gust velocity are shown in Fig. 58 for gross weights of 221,600 lb. and 186,000 lb. These values were obtained from the dynamic loads solution for points on the design cruise speed boundary of 375 kt. EAS



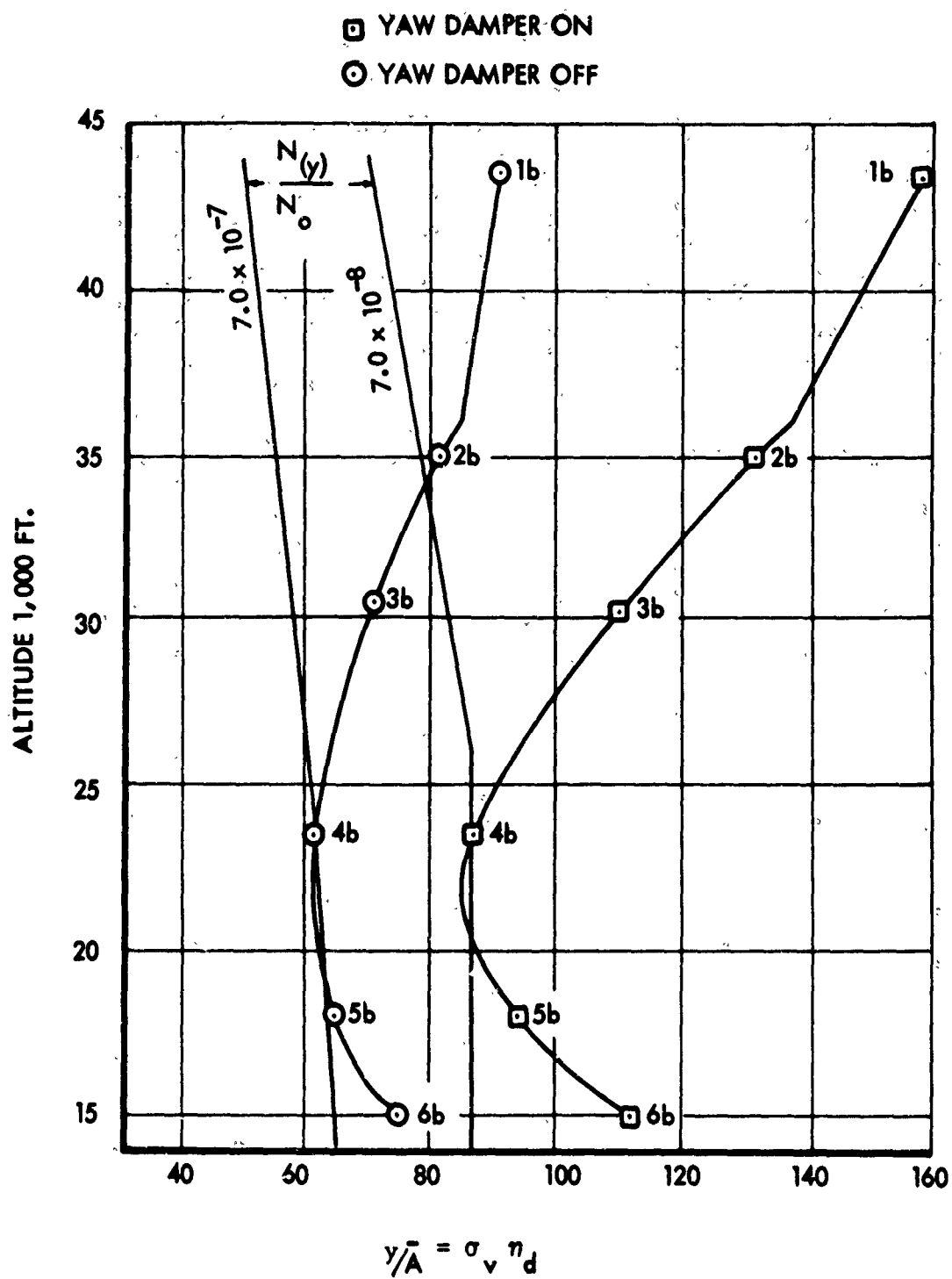


FIGURE 51. VARIATION OF FIN BENDING MOMENT  $\sigma_v \eta_d$  WITH ALTITUDE

AFT BODY BENDING MOMENT  
BODY BALANCE STATION 1020

□ YAW DAMPER ON

○ YAW DAMPER OFF

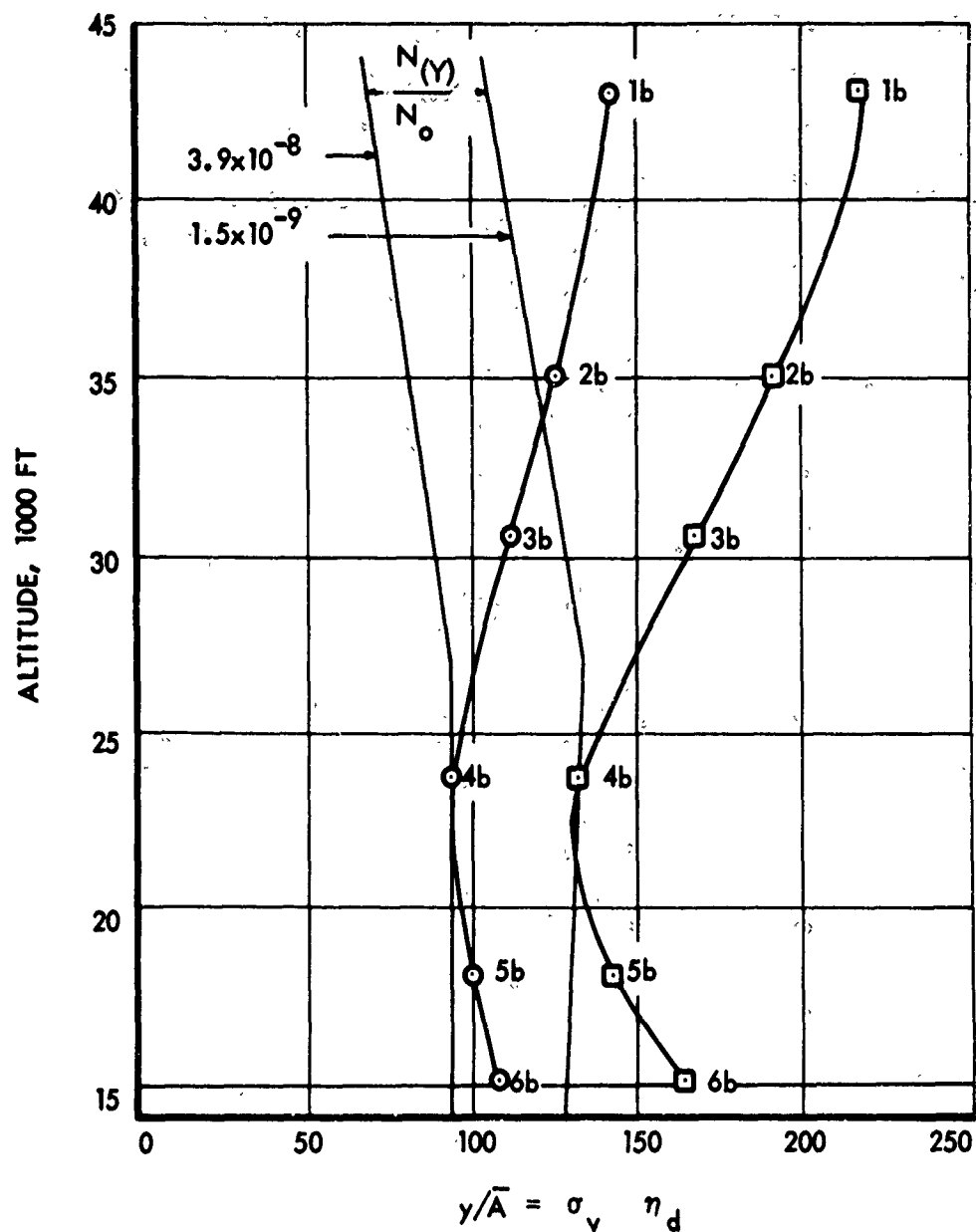


FIGURE 52. VARIATION OF BODY BENDING MOMENT  $\sigma_v \eta_d$  WITH ALTITUDE

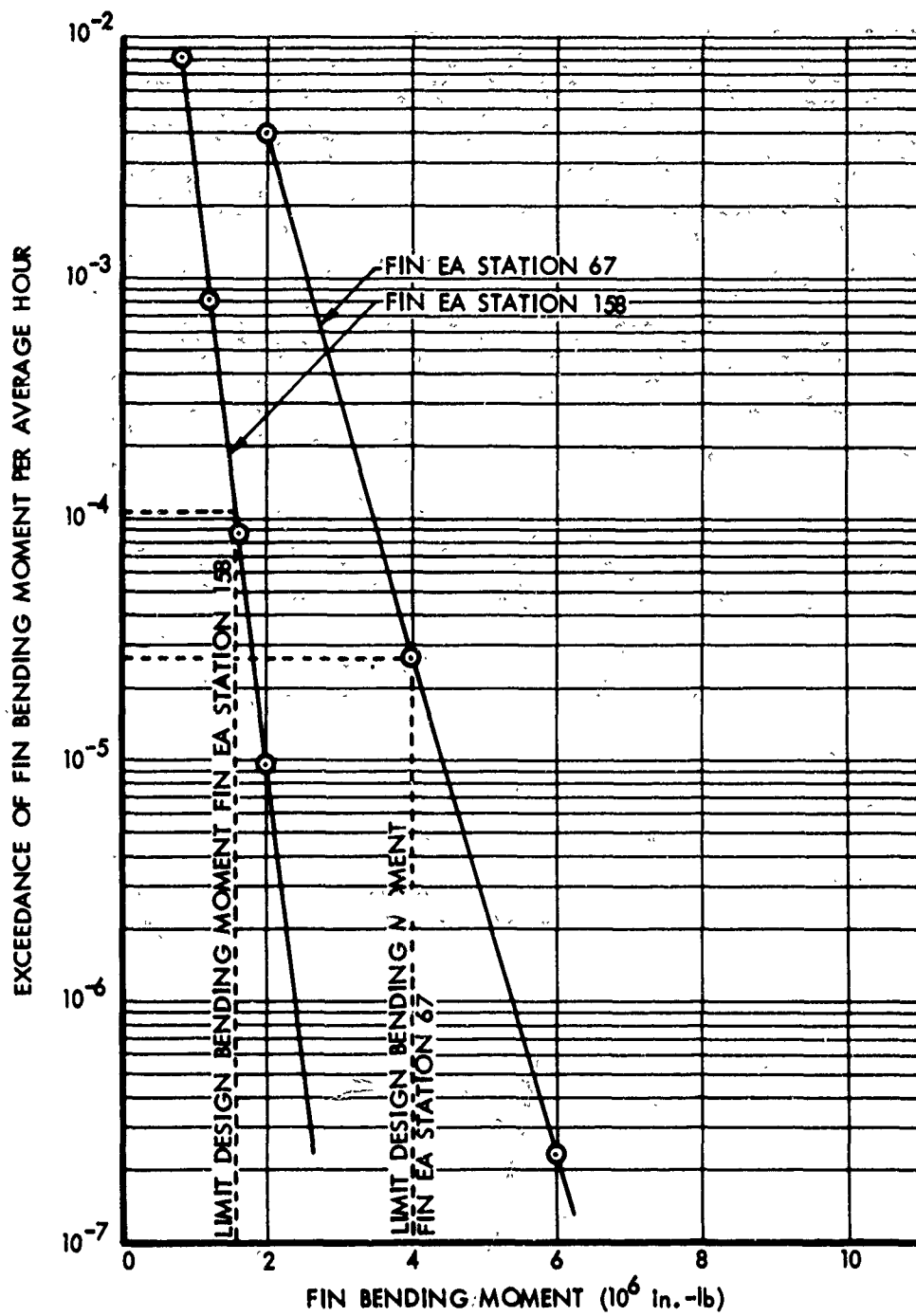


FIGURE 53. EXCEEDANCES OF FIN BENDING MOMENT, YAW DAMPER OFF

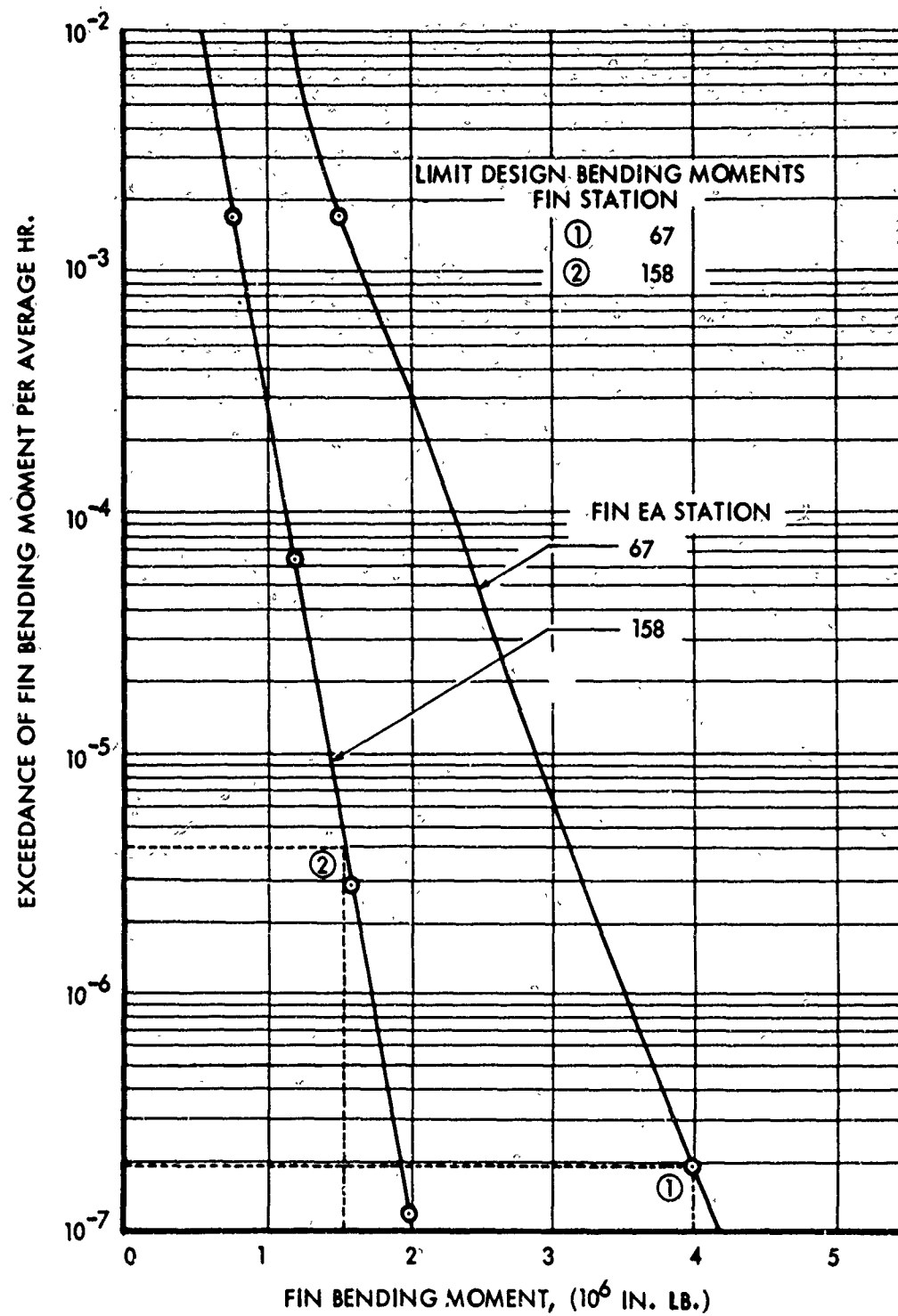


FIGURE 54. EXCEEDANCES OF FIN BENDING MOMENT, YAW DAMPER ON

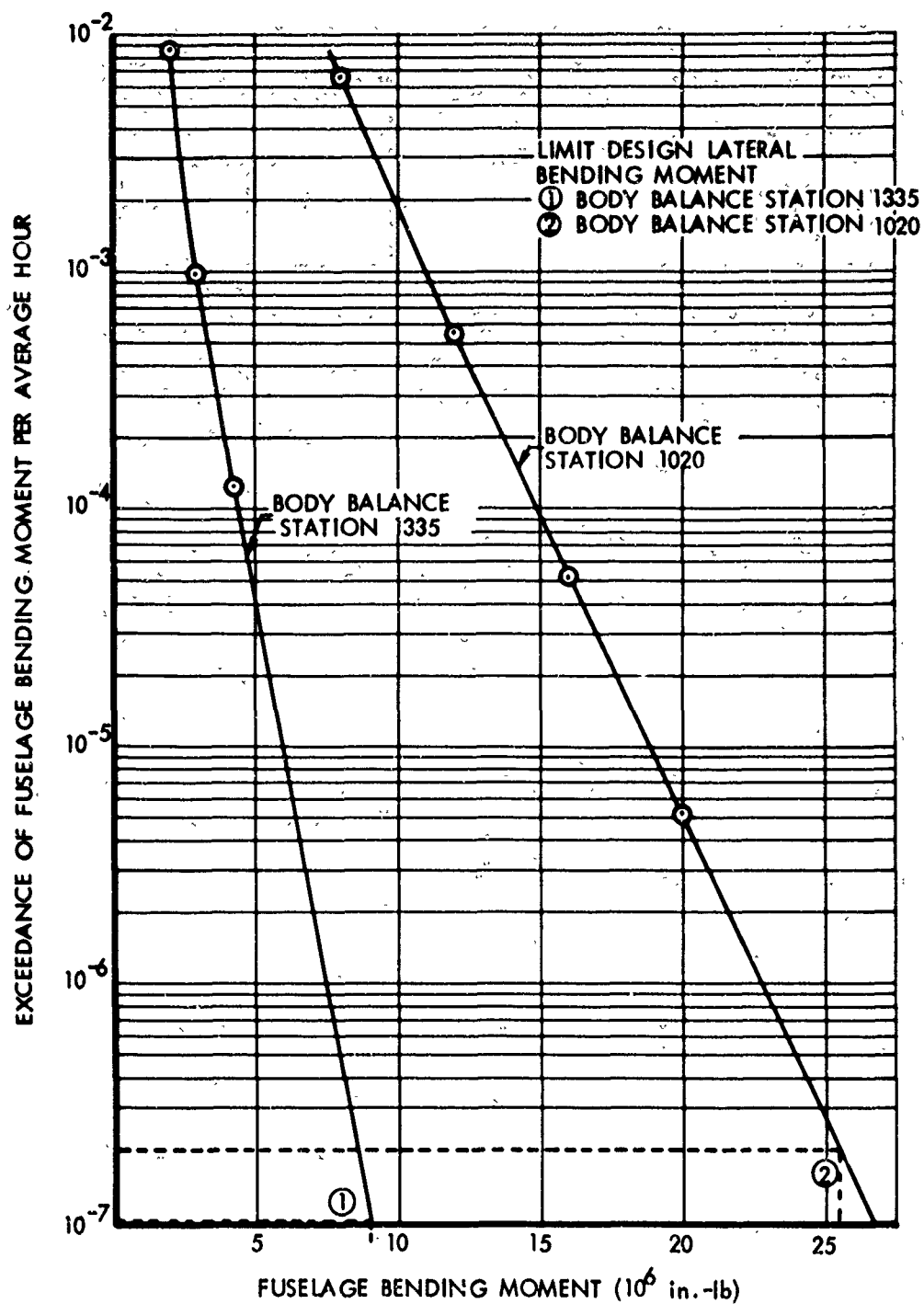


FIGURE 55. EXCEEDANCES OF FUSELAGE LATERAL BENDING MOMENT, YAW DAMPER OFF

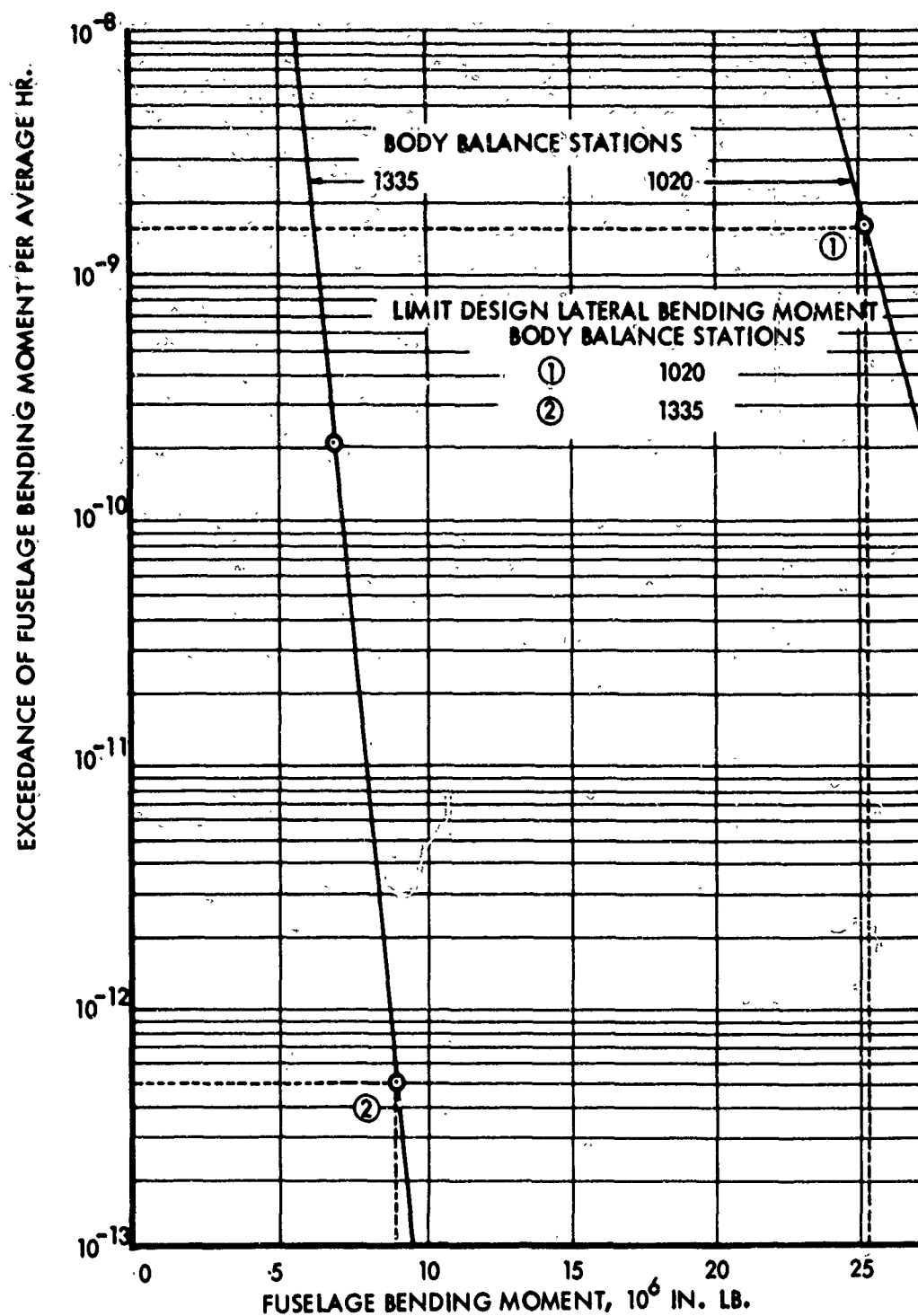


FIGURE 56. EXCEEDANCES OF FUSELAGE LATERAL BENDING MOMENT, YAW DAMPER ON

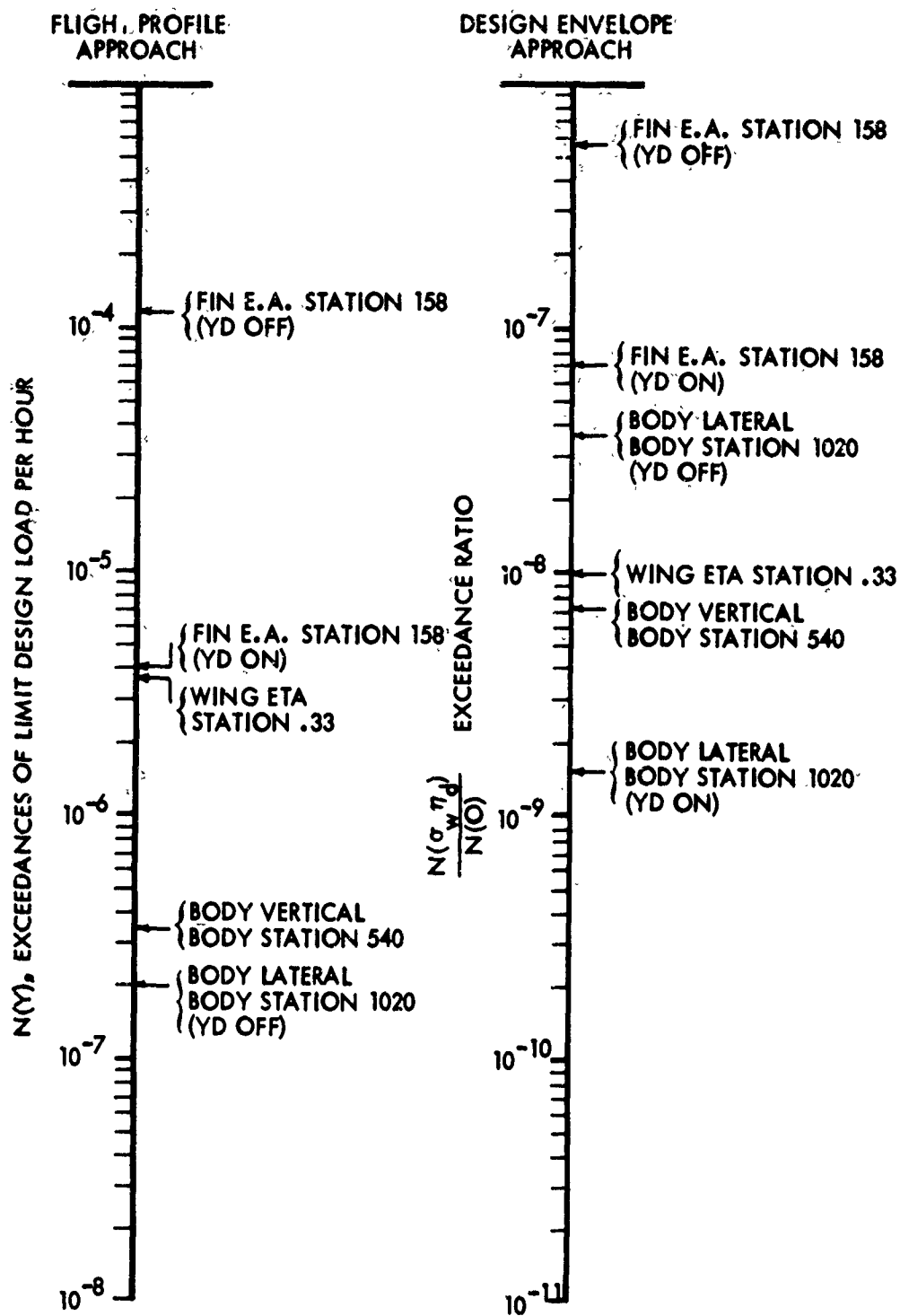
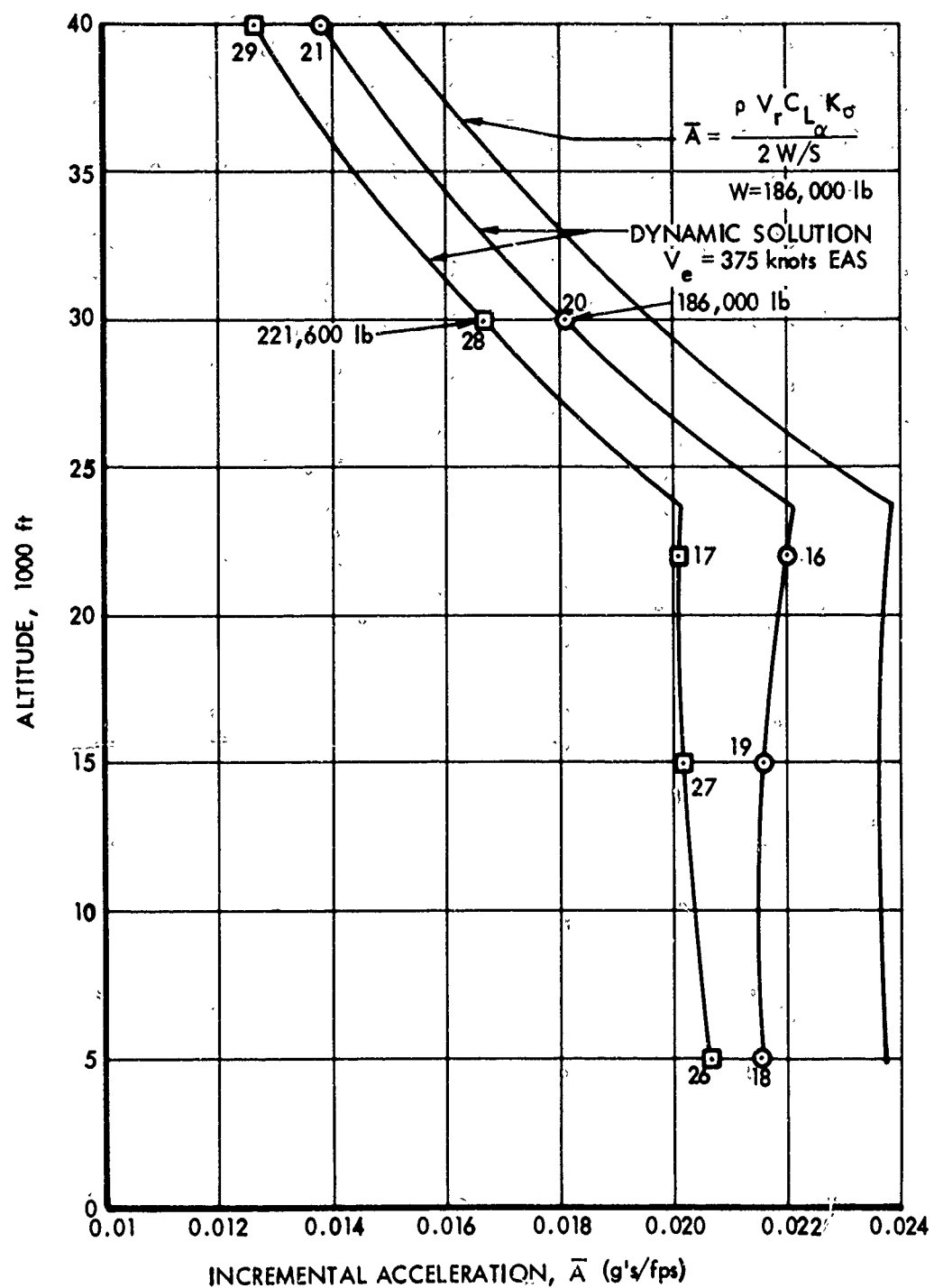


FIGURE 57. SUMMARY OF DESIGN VALUES OF EXCEEDANCE RATIOS AND FREQUENCY OF EXCEEDANCES BASED ON BENDING MOMENTS



INCREMENTAL ACCELERATION,  $\bar{A}$  (g's/fps)  
 FIGURE 58. ALTITUDE VARIATION OF INCREMENTAL CG ACCELERATION



to Mach .90. As a matter of interest, the  $\bar{A}$  values for 186,000 lb. gross weight were also calculated using the one dimensional expression developed by Y. C. Fung<sup>(16)</sup> and given below:

$$\bar{A}_{An} = \frac{\rho V_T C_{La}}{2(W/S)} K_{\sigma} \quad (19)$$

where,

- $\rho$  atmospheric density at altitude, slugs per cu. ft.
- $V_T$  true airspeed, ft. per sec.
- $C_{La}$  flexible airplane life curve slope, per rad.
- $W$  airplane gross weight, lb.
- $S$  airplane wing area, ft.
- $K_{\sigma}$  gust response factor based upon the isotropic turbulence spectrum and a scale of turbulence factor of 2500 ft.

The  $\bar{A}_{An}$  values determined by the one-dimensional equation are about ten percent higher than those obtained from the full dynamic solution. This difference can be attributed to flexibility and aerodynamic effects which are more precisely accounted for in the dynamic solution.

Values for the frequency of exceedance per hour for incremental center of gravity acceleration are shown in Fig. 59. These values were determined from flight profile analysis. The cg acceleration exceedances for the 707-300 series airplanes are also shown in Fig. 59. These data were collected by NASA from actual airline operations<sup>(3)</sup>. At the time of this report, sufficient acceleration data was not available for the 720B airplane, so an attempt was made to adjust the 707-300 data to represent 720B usage. This adjusted data can be compared to the 720B analytical data in Fig. 59. This comparison indicates that the predicted cg acceleration exceedances are somewhat higher than the adjusted usage values. The disagreement increases as the acceleration level increases. This would indicate that the turbulence intensity parameters,  $P_1$ ,  $P_2$ ,  $b_1$ , and  $b_2$  should be readjusted.

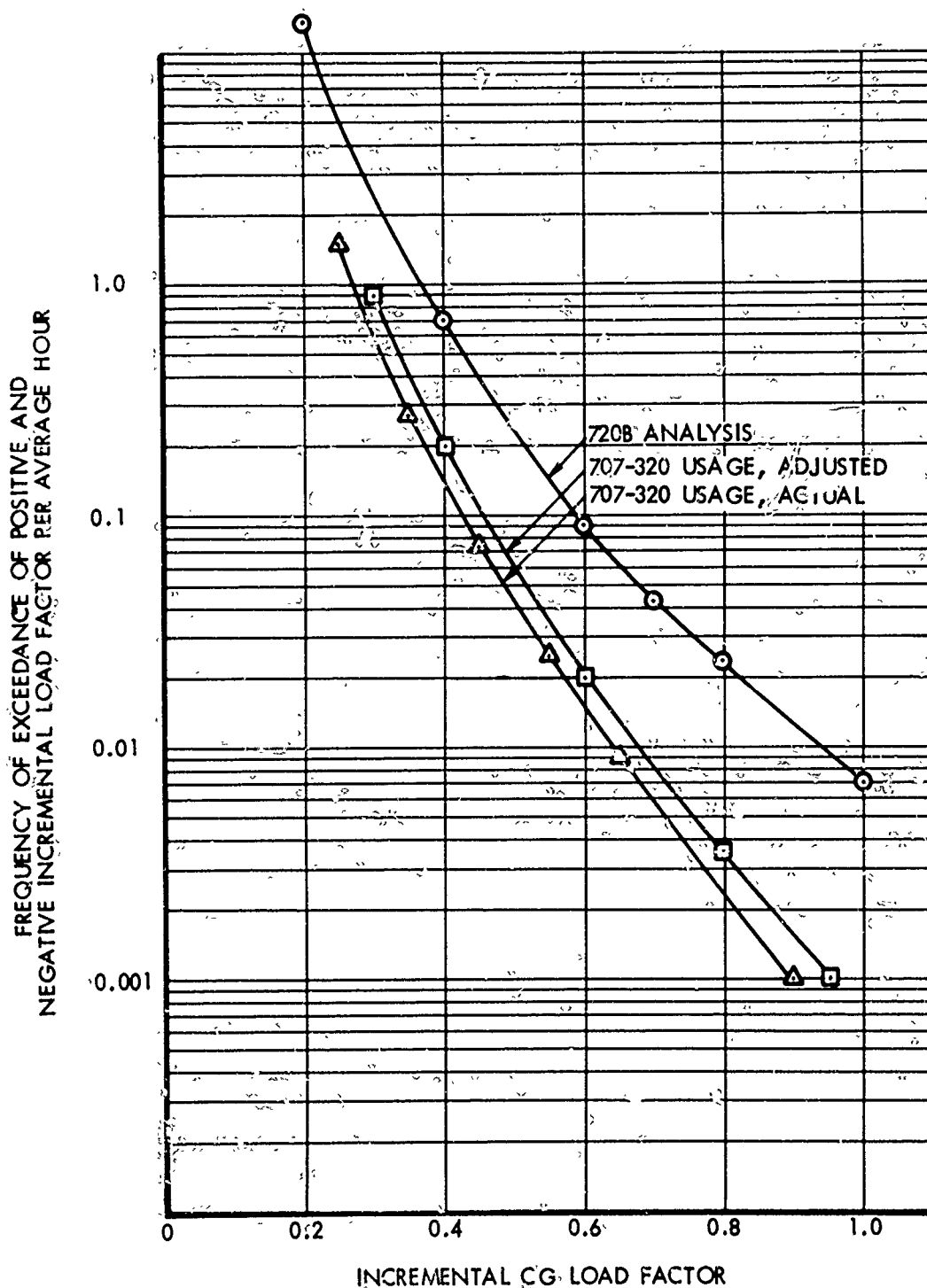


FIGURE 59. EXCEEDANCES OF INCREMENTAL CG ACCELERATION

### Boeing Analysis Results for Lockheed Model 749

A comparative analysis was conducted by The Boeing Company on the Lockheed Model 749 airplane. The Lockheed-California Company furnished the basic airplane data in the form of lumped mass distribution, bending and torsional stiffness distributions, wing lift distribution, and basic airplane lift and moment data. From this description, the analysis was conducted by Boeing using the analysis procedures used for the 720B study. The results of this analysis are expressed as  $\bar{A}$ , the rms load due to a one ft. per sec. rms gust velocity, and  $N_0$ , the number of zero crossings per second for wing shear, bending moment, and torsion. A comparison of these values with those obtained by Lockheed are shown in Figs. 60 and 61. Values for  $\bar{A}$  and  $N_0$  for cg incremental acceleration are also listed. The agreement between the Boeing and Lockheed  $\bar{A}$  values is generally not as good as might be desired. Possible reasons for this disagreement are explored in Reference 18. The agreement of the  $N_0$  values is seen to be much more satisfactory.

### Parametric Variations - Vertical Analyses

The results of the parametric variations conducted for the vertical analyses are shown in Fig. 62 as they affected the rms wing bending moment at the critical wing station. Fig. 63 shows how these parametric variations affect the airplane incremental cg acceleration. The trends exhibited by bending moment and cg acceleration are similar for all variations except for the variation of wing torsional stiffness. In this case, a reduction in wing torsional stiffness of 20 percent resulted in a slight, less than one percent, increase in cg acceleration while the rms wing bending moment actually decreased by one percent. The wing rms bending moment and incremental cg acceleration are quite insensitive to variations in wing torsional stiffness.

When gradual penetration effects were neglected, the resulting rms wing bending moment and the airplane incremental cg acceleration were reduced by 10-12 percent. This implies that results obtained from analyses in which gradual penetration was neglected may be unconservative. The rms wing bending moments and incremental cg acceleration were also affected by the inclusion of structural damping. Including structural damping in the amount of  $g = .03$  reduced the rms wing bending moment and cg acceleration levels from 5 to 8 percent. Moving the airplane center of gravity aft by 9 percent of the MAC increased the wing bending moment and cg acceleration 2 to 3 percent.

The rms wing bending moment level was reduced about 8 percent when the wing bending stiffness was decreased to 80 percent of its nominal value.

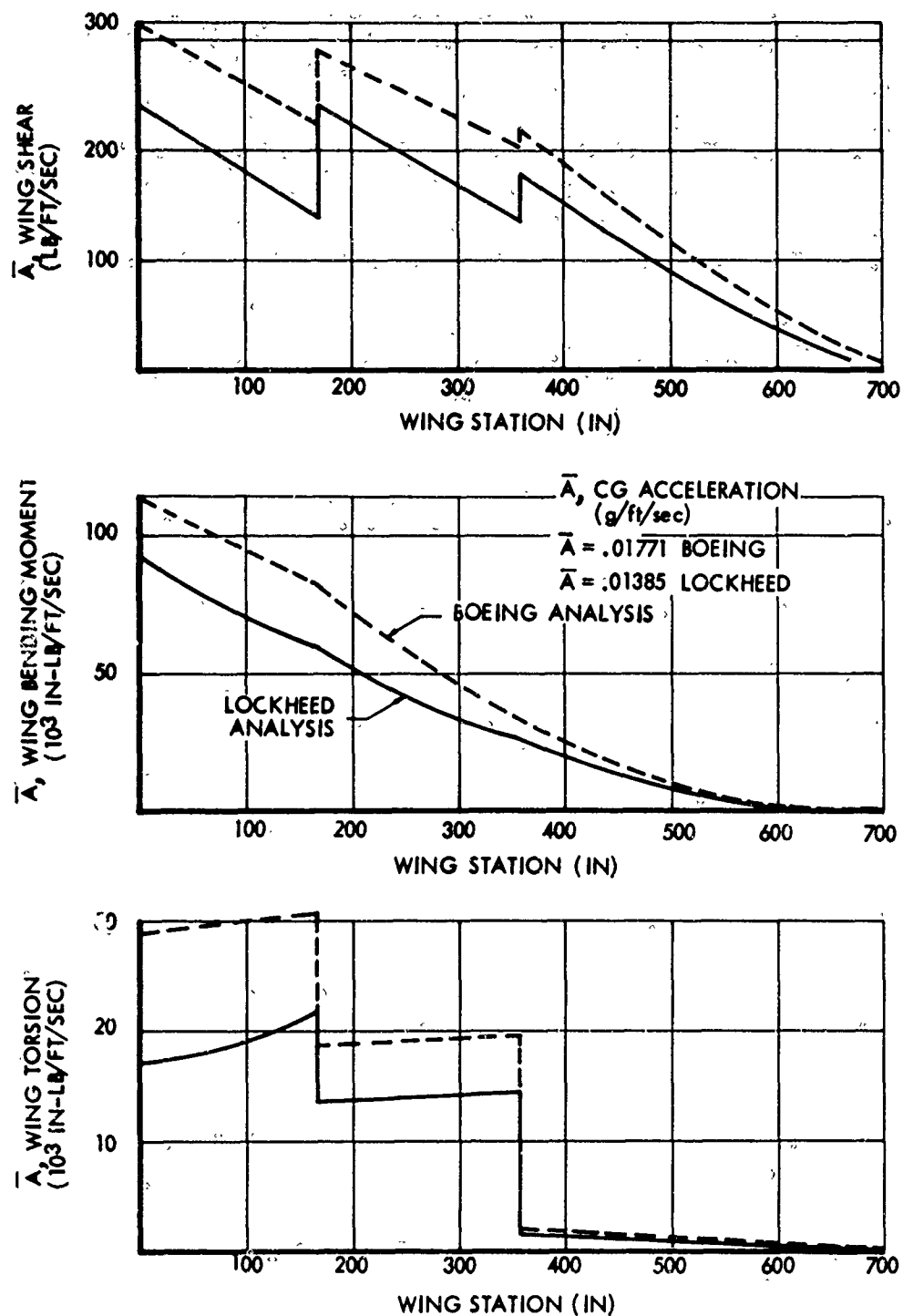
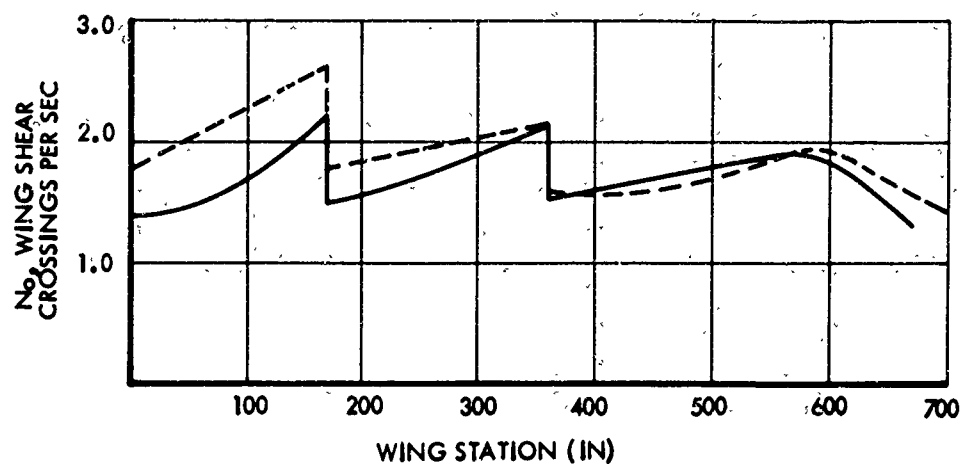


FIGURE 60. COMPARISON OF RMS LOADS FOR THE LOCKHEED MODEL 749



$N_0$ , CG ACCELERATION  
ZERO CROSSING PER SEC

$N_0 = 1.173$  BOEING

$N_0 = 1.354$  LOCKHEED

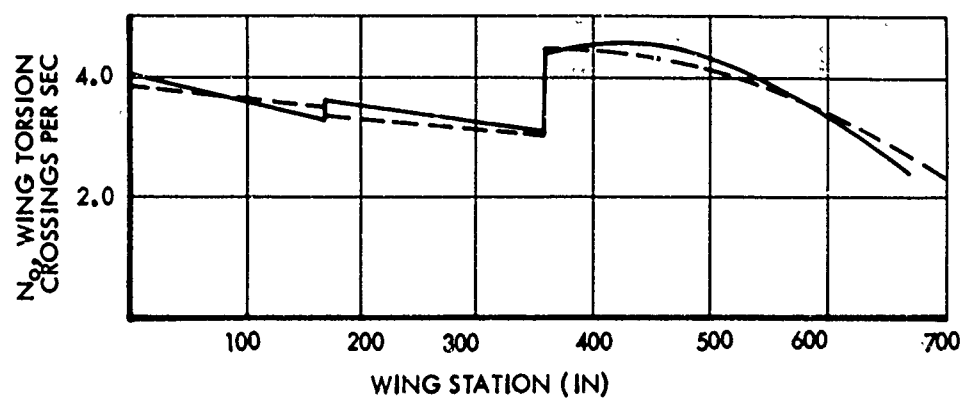
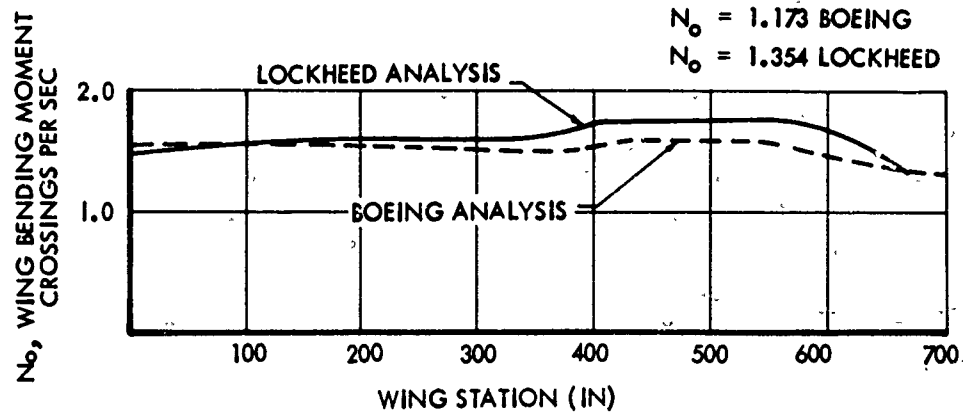


FIGURE 61. COMPARISON OF NUMBER OF ZERO CROSSINGS

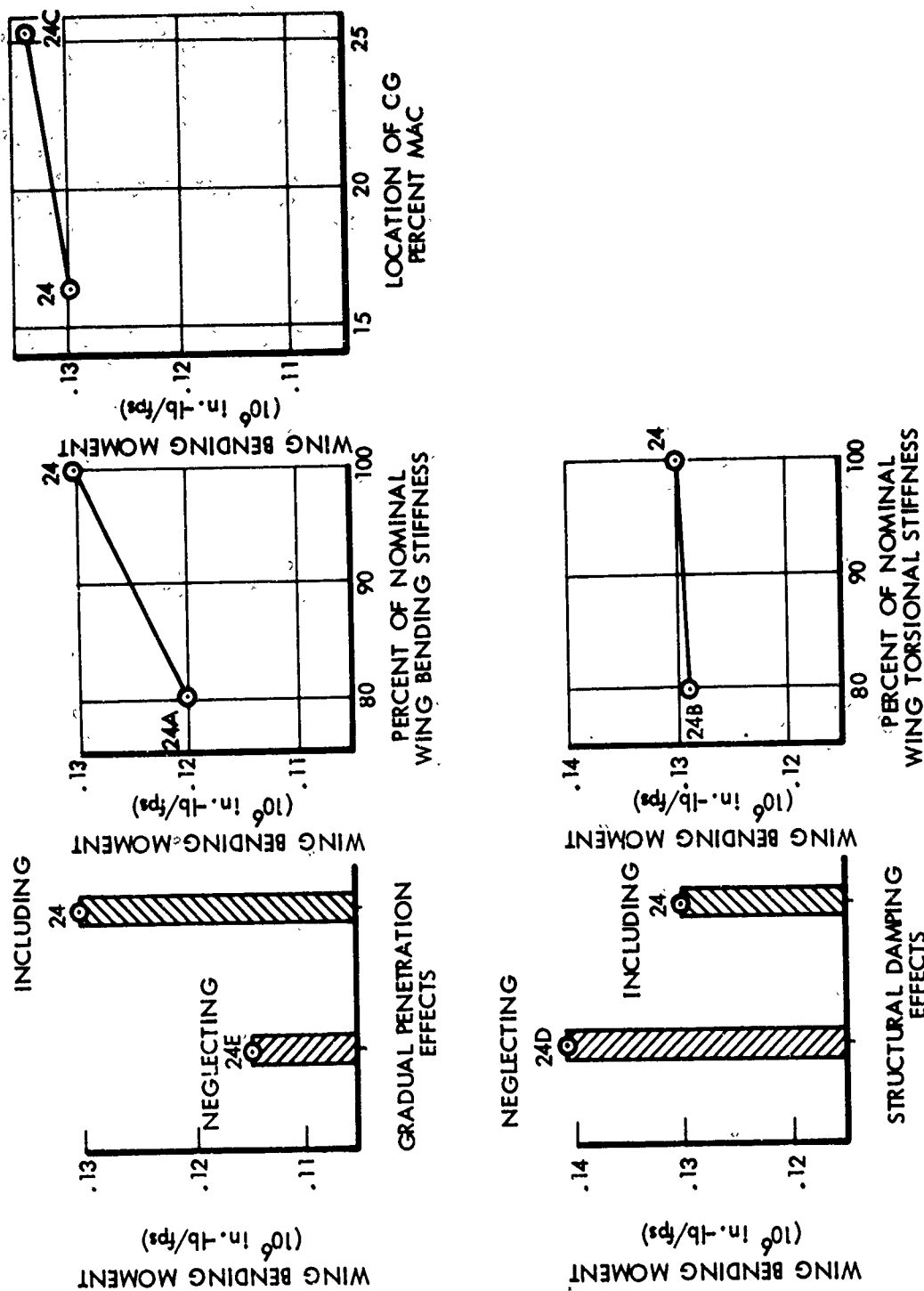


FIGURE 62. WING BENDING MOMENT RESULTS OF PARAMETRIC VARIATIONS, VERTICAL ANALYSES

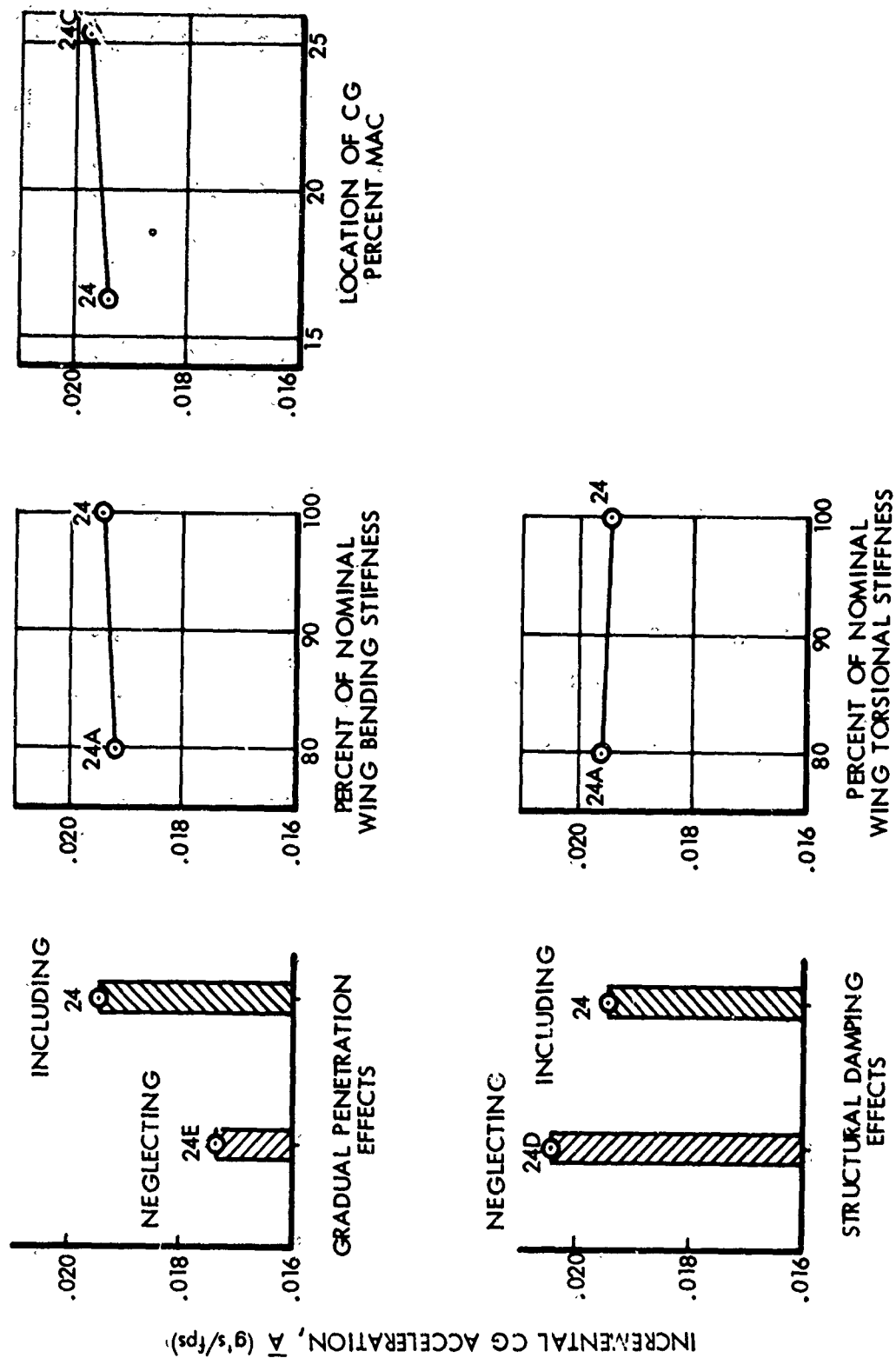


FIGURE 63. CG ACCELERATION RESULTS OF PARAMETRIC VARIATIONS, VERTICAL ANALYSES

The general conclusions that can be drawn from the vertical analyses parametric variations is that the dynamic analyses should include gradual penetration and structural damping effects.

#### Parametric Variations - Lateral Analyses

The results of the parametric variations conducted for the lateral analysis are given in terms of vertical tail bending moment at Fin Elastic Axis Station 158. These results are shown in Figs. 64 through 66(c). Variations in  $\bar{A}$  for fin shear, bending moment, and torsion are shown in Fig. 64 for changes in airplane gross weight. The gross weight changes were made by adding wing fuel. The addition of wing fuel causes a corresponding increase in airplane yaw and roll inertia. The trends in the rms loads, therefore, reflect the influence of these inertia changes as well as the weight changes. These results indicate a 11 percent increase in the rms fin loads for a 25 percent increase in gross weight.

The variation in  $\bar{A}$  for fin loads, resulting from changes in altitude, with gross weight, Mach number and true airspeed constant at 475 kt., are shown in Fig. 65. The effects of increasing altitude under these circumstances is to decrease the dynamic pressure and decrease Dutch roll damping. The reduction of Dutch roll damping would tend to increase the resulting loads; however, for this airspeed, the reduction of dynamic pressure more than offsets the effect of the damping loss, and the end result was an overall decrease in the loads. Previous studies on similar airplanes indicate that increasing the altitude at reduced airspeeds can increase the loads significantly due to a loss of Dutch roll stability.

The curves in Figs. 66(a) through 66(c) show the effects on rms fin loads of variations in the yaw damping derivative,  $C_{n_{\dot{\psi}}}/2V$ , the yaw-roll coupling derivative,  $C_{n_{\dot{\phi}}}/2V$ , and the airplane product of inertia,  $I_{xy}$ .

As was mentioned previously in Analysis, the lateral gust loads are closely associated with the Dutch roll damping. When the Dutch roll damping is large, variation in the damping derivatives and airplane product of inertia have only a small effect on the lateral dynamic loads; however, when the amount of inherent Dutch roll damping is low, these same parameters can have a tremendous effect on the dynamic stability and the resultant dynamic loads.

#### Statistical Correlation Between Wing Loads

Prior to conducting the detailed combined stress analysis it was decided to obtain the correlations between the wing shear, bending moment and torsion loads. These correlation coefficients were obtained for each



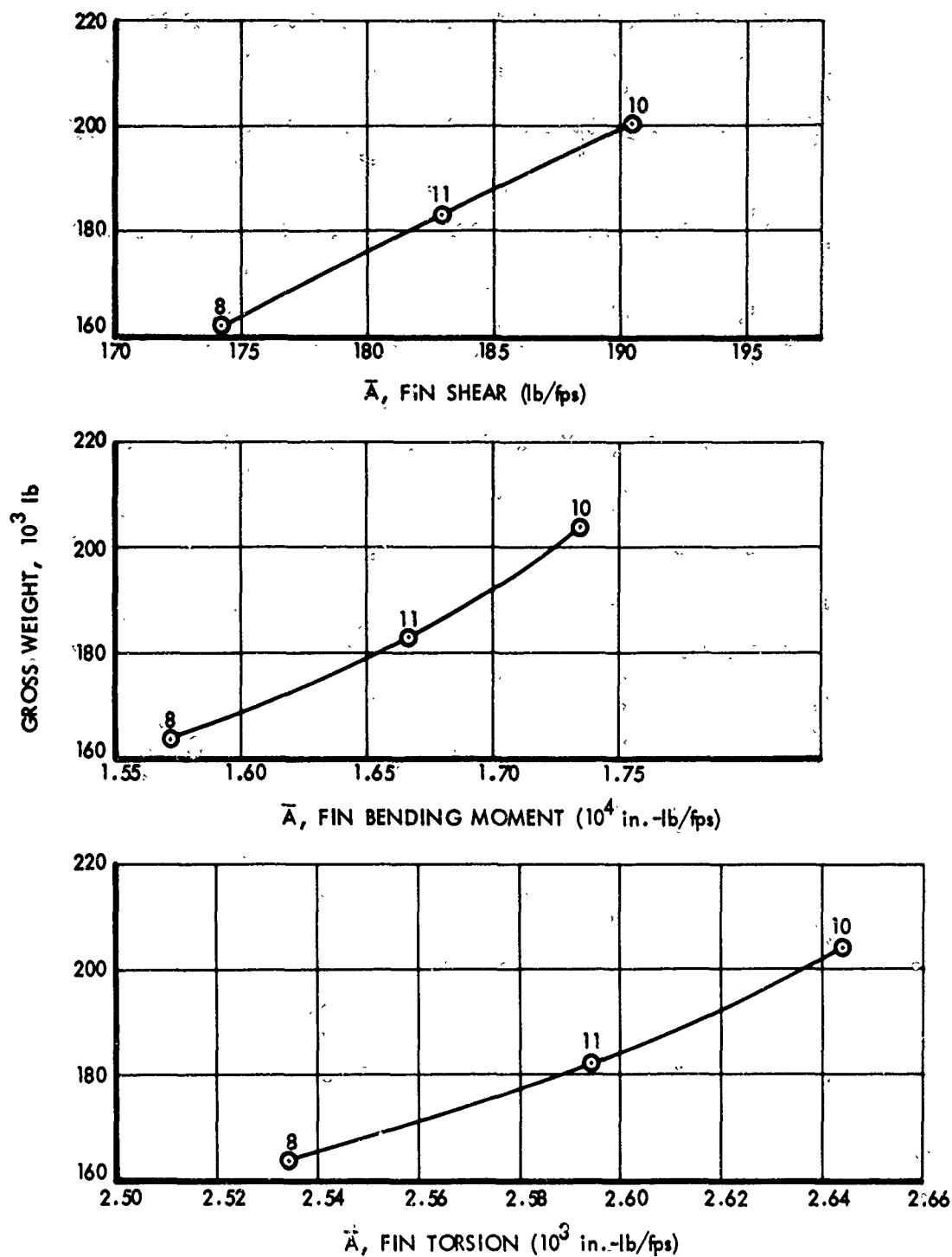


FIGURE 64. VARIATION OF RMS FIN LOADS WITH GROSS WEIGHT,  
FIN E.A. STATION 158

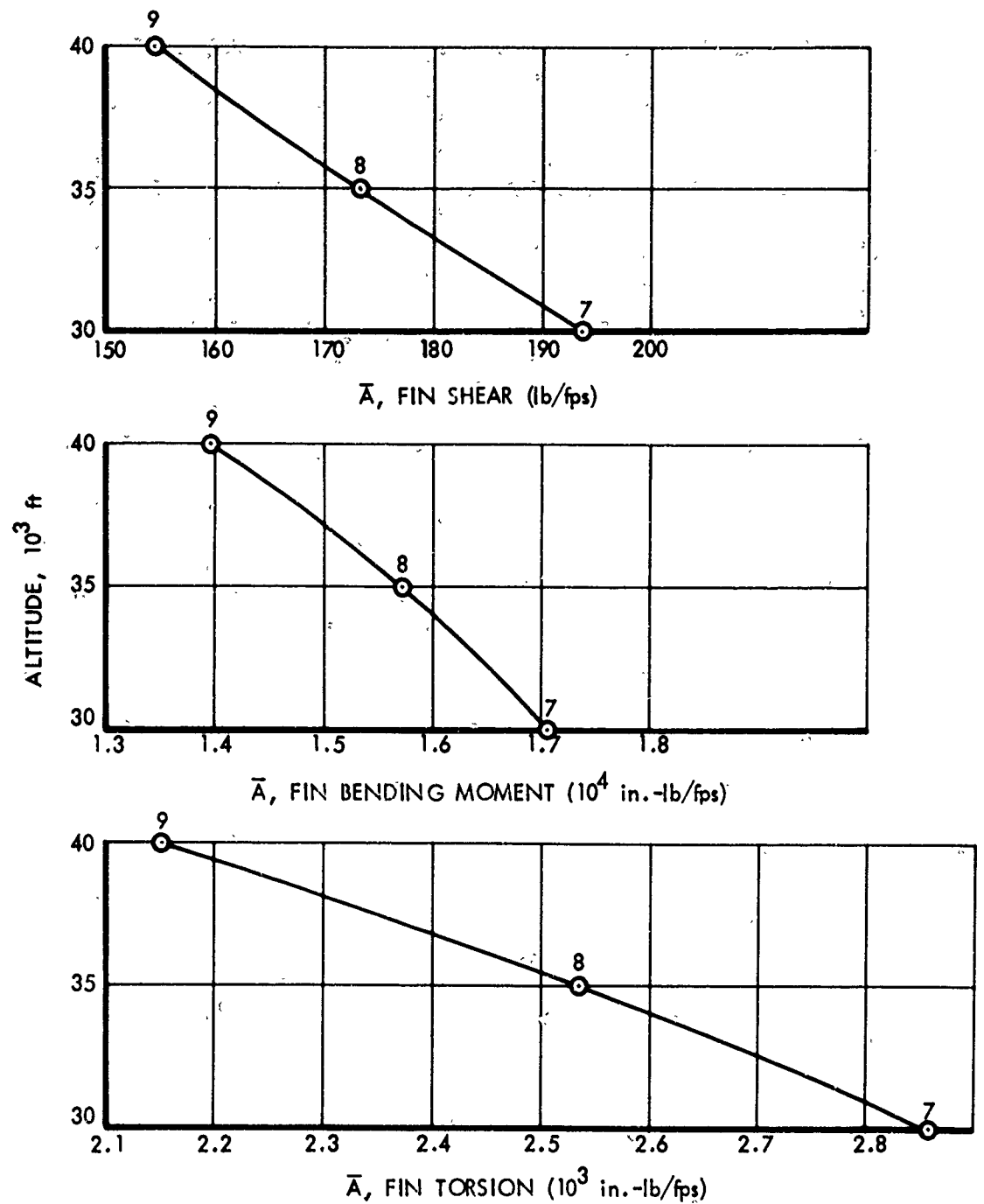


FIGURE 65. VARIATION OF RMS FIN LOADS WITH ALTITUDE, FIN E.A. STATION 158

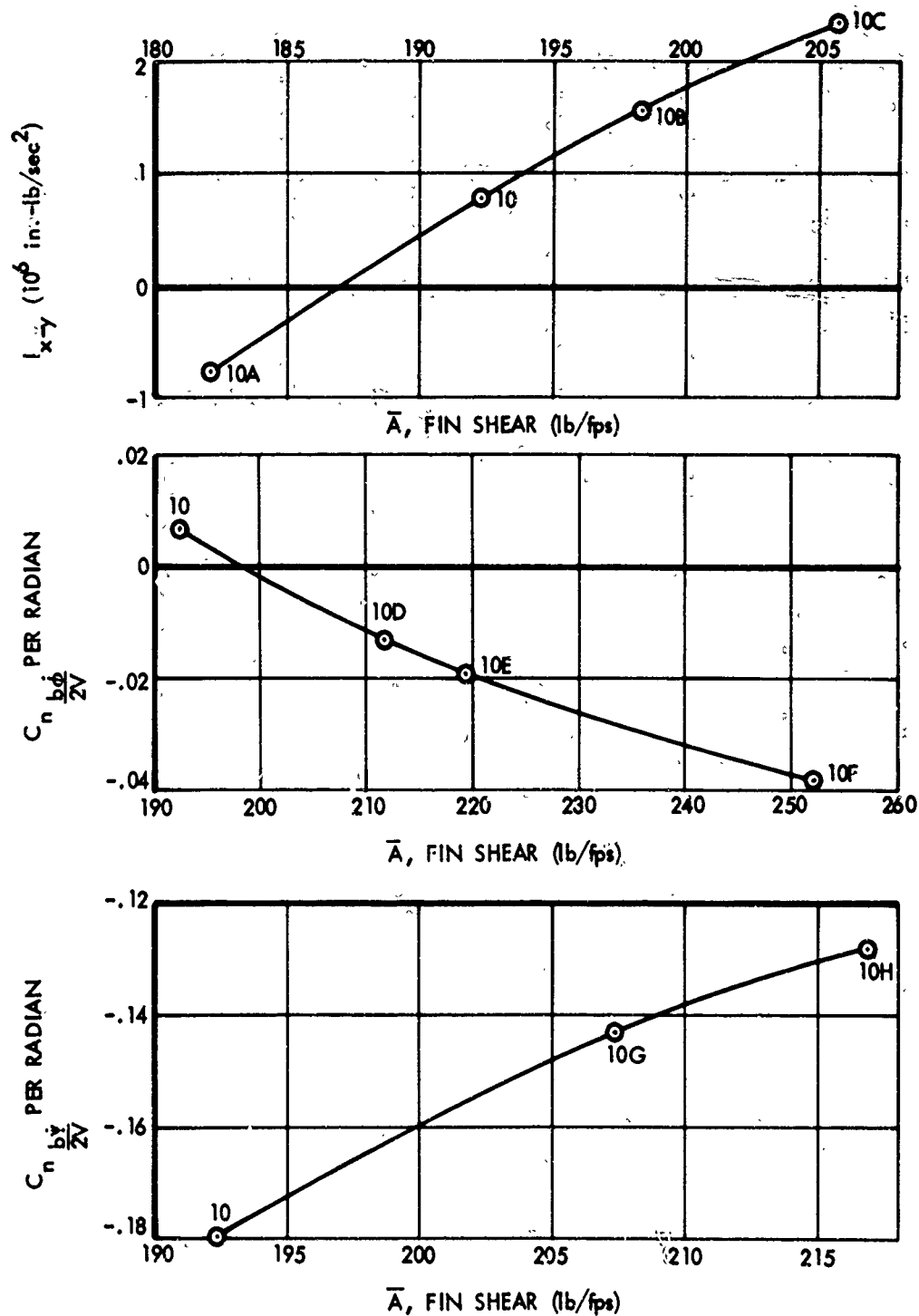


FIGURE 66. (a) FIN SHEAR RESULTS OF PARAMETRIC VARIATIONS, LATERAL ANALYSES, FIN E.A. STATION 158

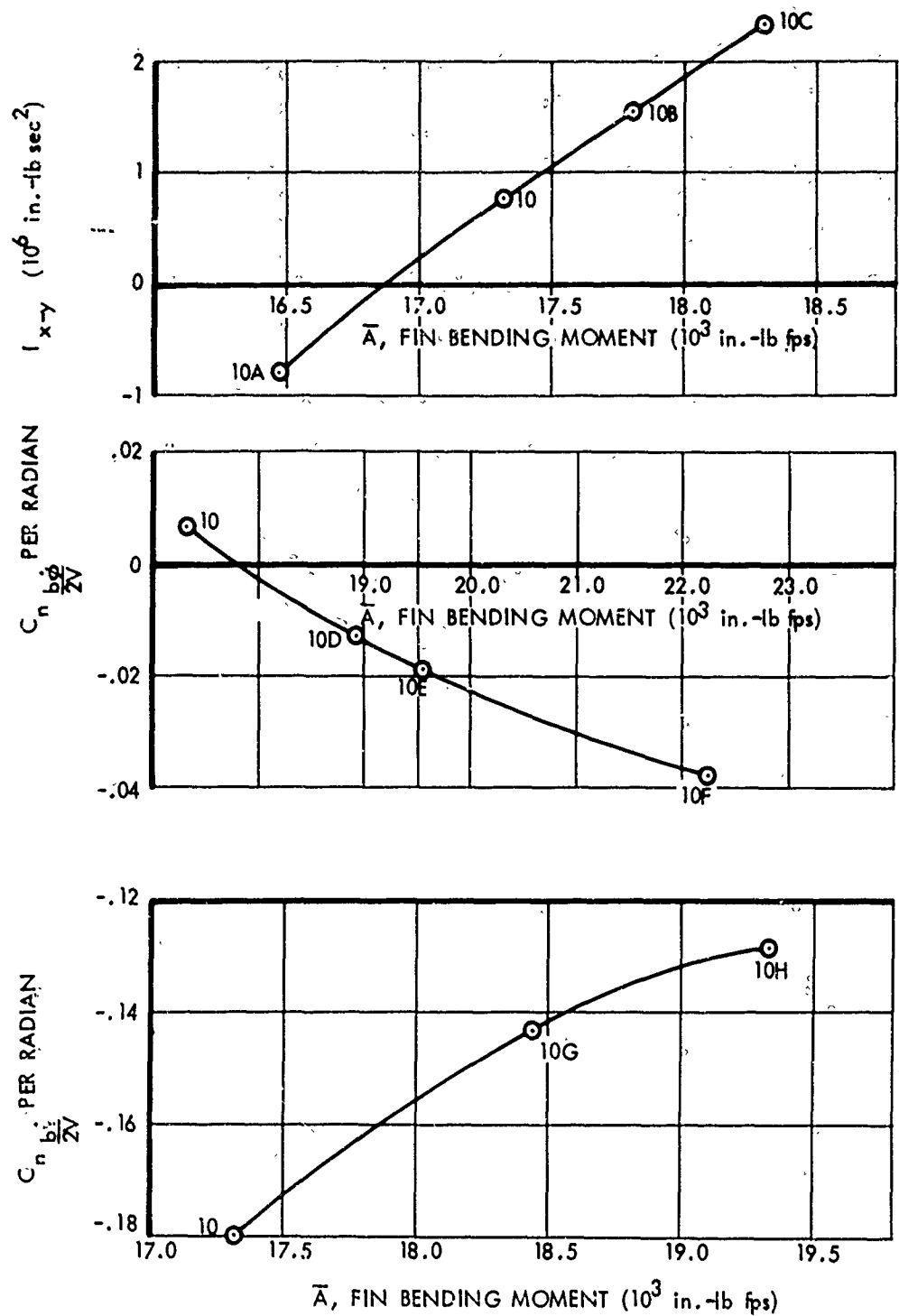


FIGURE 66. (b) FIN BENDING MOMENT RESULTS OF PARAMETRIC VARIATIONS, LATERAL ANALYSES

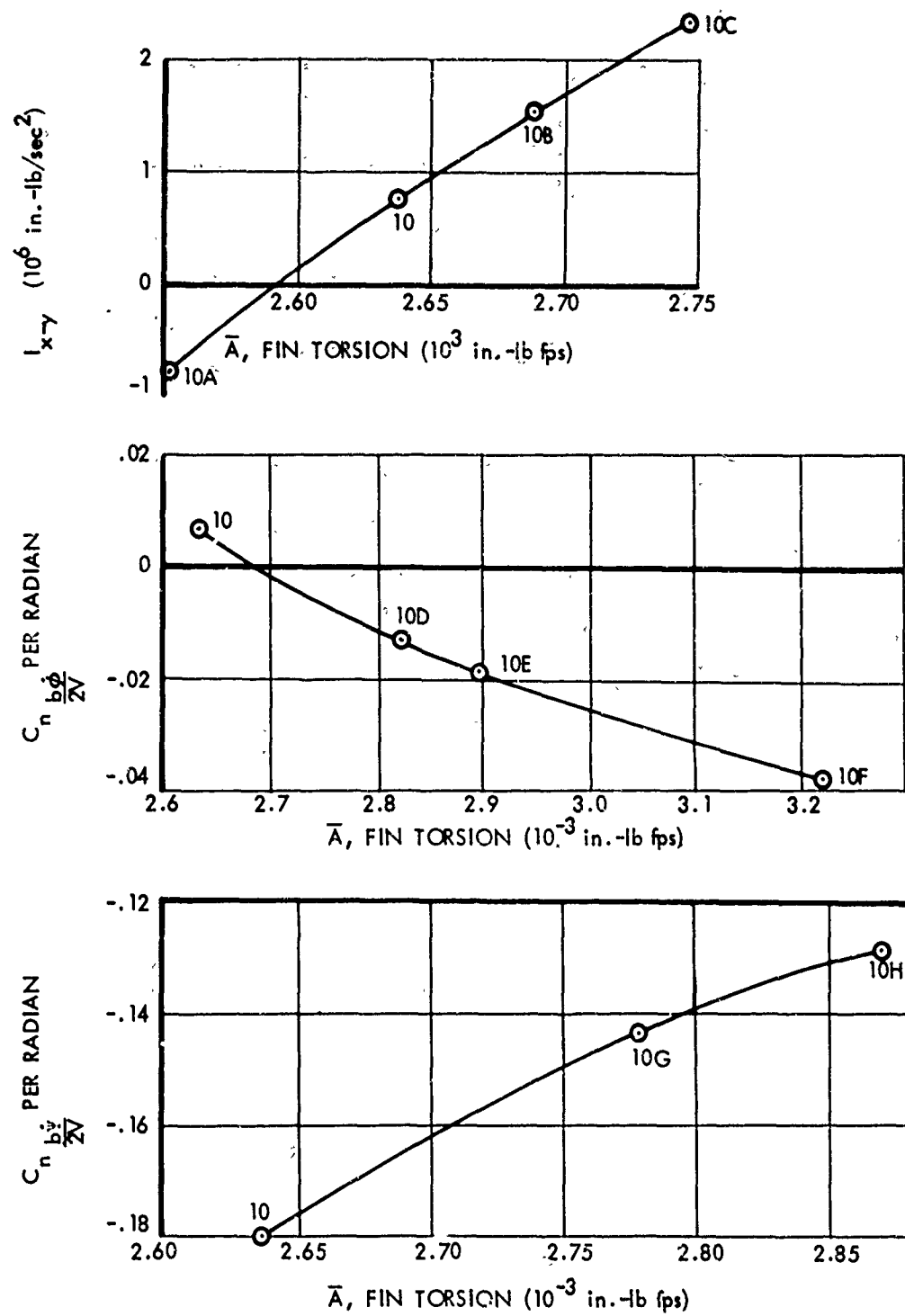


FIGURE 66 (c). FIN TORSION RESULTS OF PARAMETRIC VARIATIONS, LATERAL ANALYSES

set of load quantities using cross power spectral density equations derived in Appendix B. The results are plotted versus Wing Eta Station in Fig. 67.

Outboard of the outboard nacelle the wing shear and bending moment are almost exactly correlated while the torsion and bending moment are correlated very poorly. This indicates that shear and bending are very nearly in phase but that torsion is very nearly independent of either bending moment or shear. Inboard of the outboard nacelle, the effects of the nacelle are readily apparent. The correlation between shear and bending moment is poorer due to shear loads arising from the outboard nacelle. However, the correlation between shear and torsion is improved, due to the nacelle inertia loads. A somewhat similar tendency is shown at the inboard nacelle. The correlation between the three load quantities improves inboard of the inboard nacelle. This is a result of transferring shear and bending moment into torsion as the elastic axis sweep angle changes near the wing root.

#### Results - RMS Stress Analysis

The individual structural elements for the detailed stress analysis were selected at locations around the critical wing, body and fin stations to give the best strength evaluation possible. Included among these elements are those which demonstrated the least margin of safety as determined by the static stress analysis.<sup>(11,12,13)</sup> The numbering system used for all the elements is the same as that used in the stress analysis referenced above. In Fig. 68 is a sketch identifying the structural elements of the wing box at Wing Eta Station .33. The elements for which design values of  $\sigma_w \eta_d$  and number of exceedances were calculated are indicated by the solid circles. The structural element array and the elements analyzed for Body Stations\* 540, 1040, and 1360 are shown in Figs. 69(a), 69(b), and 69(c), respectively. The same elements were analyzed in both the lateral and vertical analyses with the exception of Forward Body Station 540 which was analyzed for the vertical analyses only. The detailed stresses for the critical Vertical Tail Elastic Axis Station 158 were calculated for the elements shown in Fig. 70. The stress analysis for the fin was conducted assuming the elements on the left and right side were symmetrical about the fin chord line.

The rms loads were transformed into axial and shear stresses using the stress coefficients obtained from the conventional stress analysis. The rms stress quantities for the structural elements at Wing Eta Station .33, Condition 24C, are shown in Tables 10(a) and 10(b). The rms shear,

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\*Corresponds to Body Balance Stations 480, 1000, and 1320 (see Fig. 21)

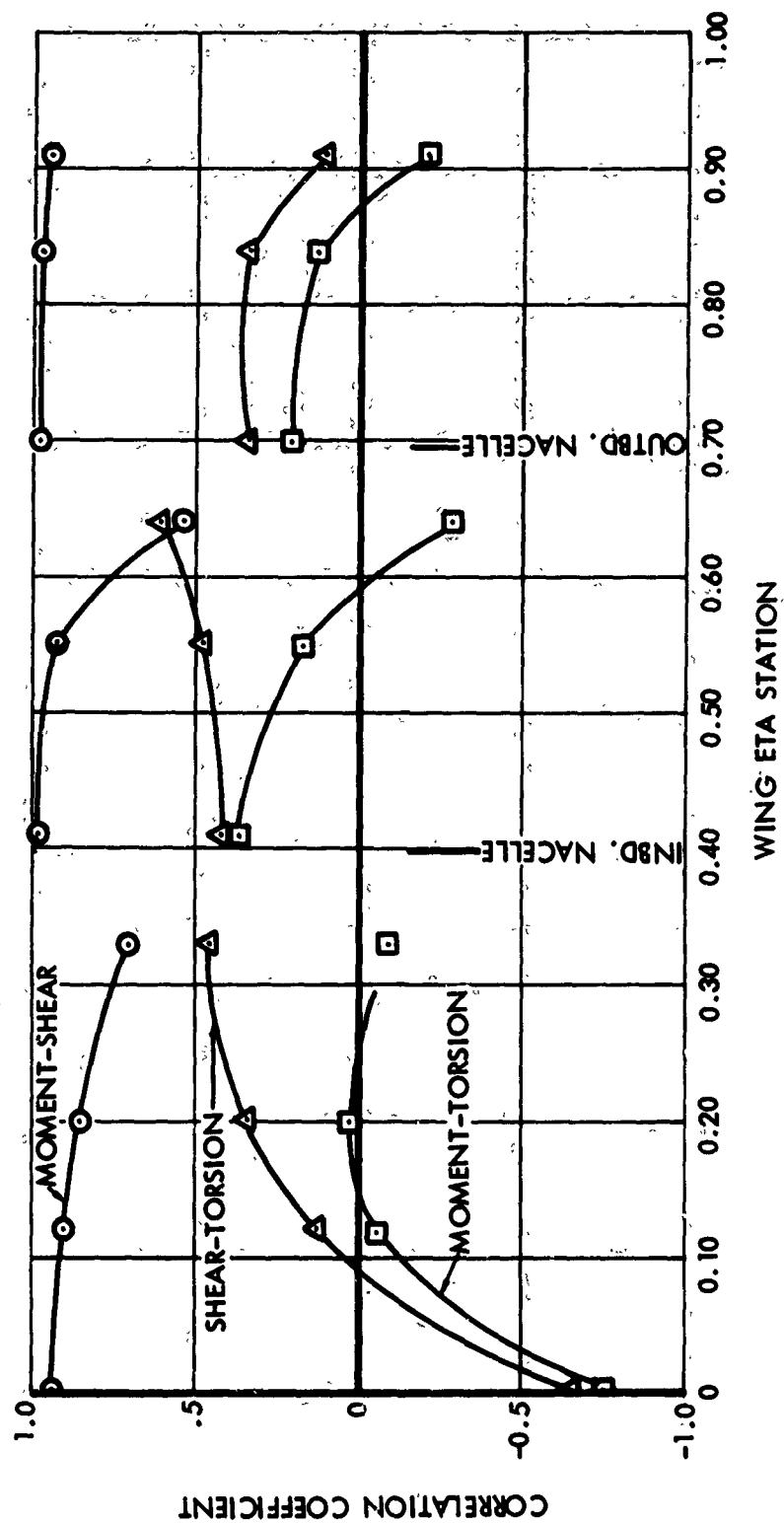


FIGURE 67. SPANWISE CORRELATION BETWEEN THE WING LOADS OF SHEAR-BENDING MOMENT-TORSION - CONDITION 24

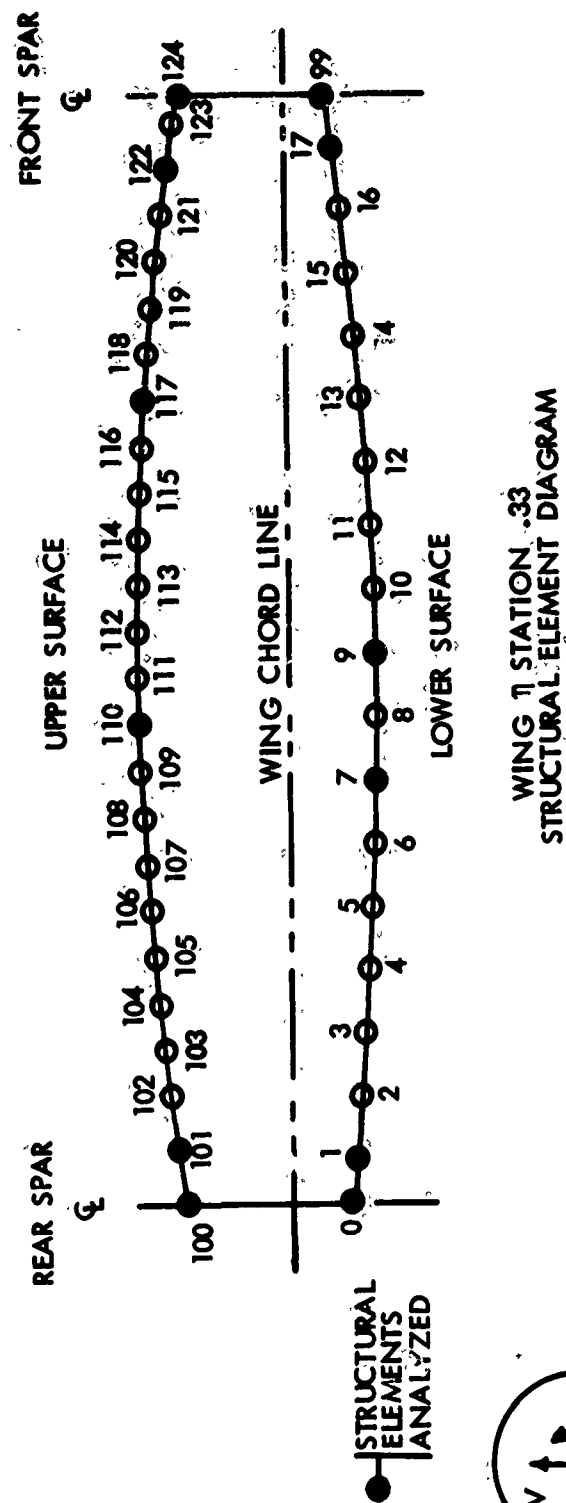


FIGURE 68. ARRAY OF STRUCTURAL ELEMENTS, WING  $\eta$  STATION .33



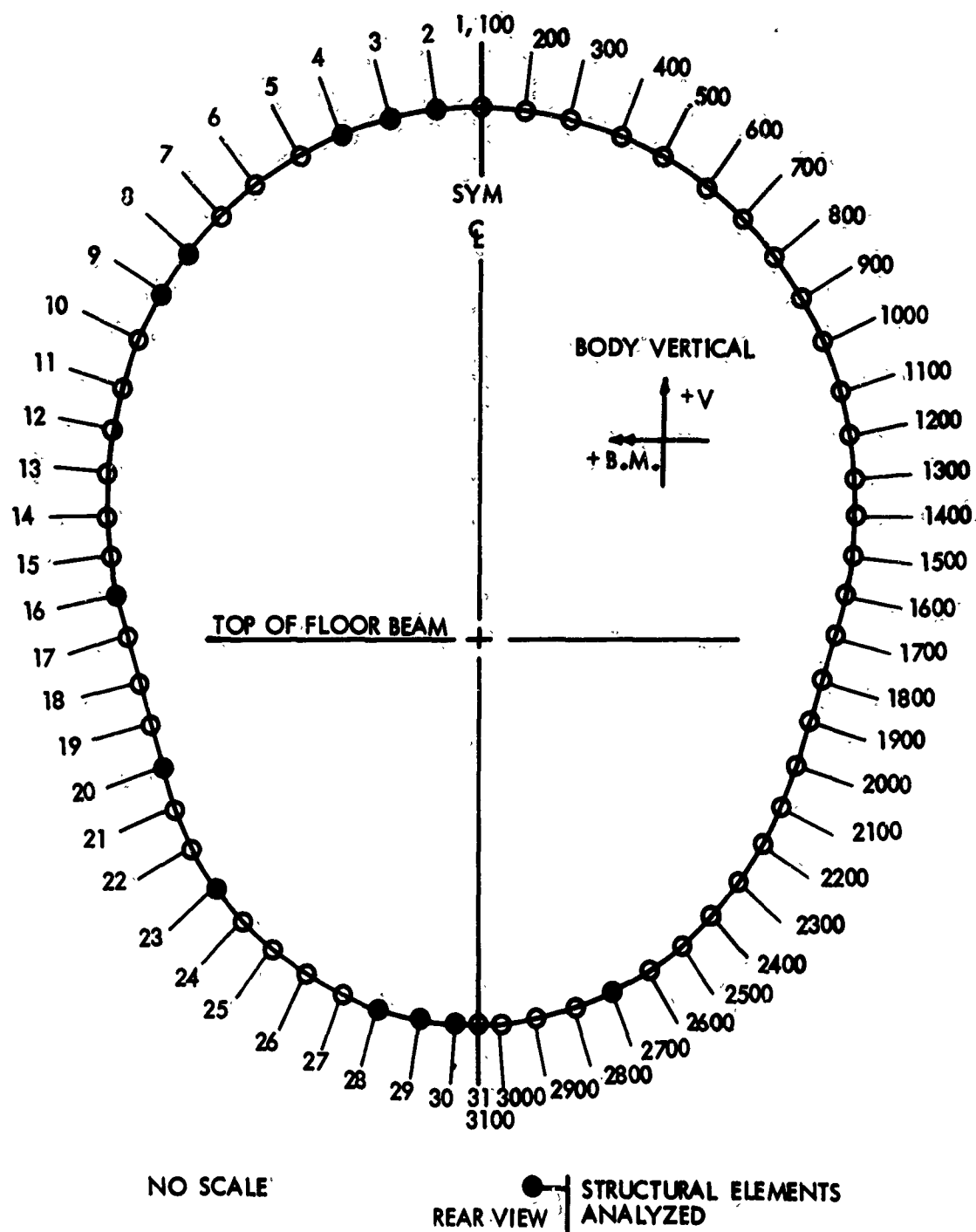


FIGURE 69 (a). ARRAY OF STRUCTURAL ELEMENTS, BODY STATION 540

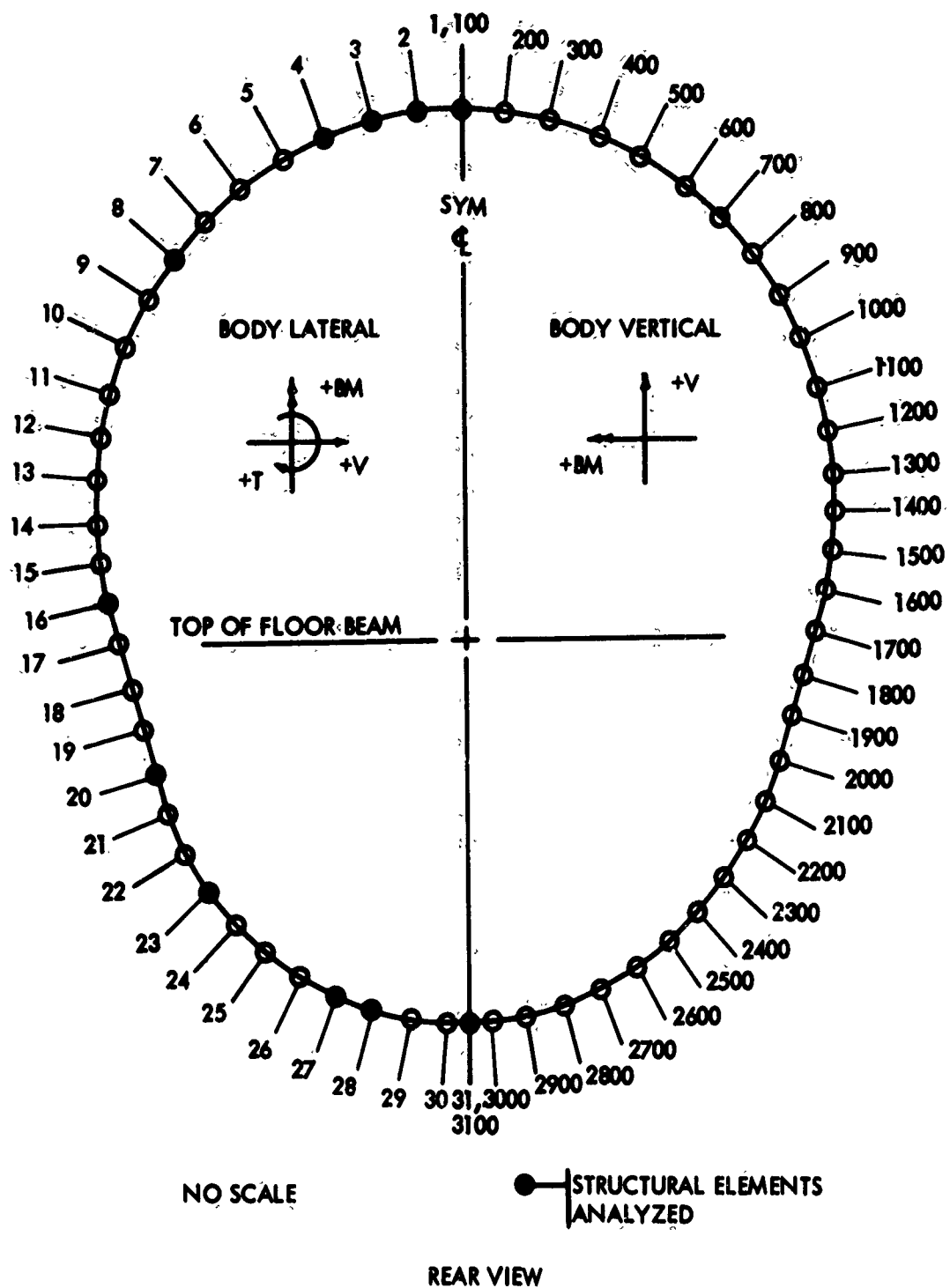


FIGURE 69 (b). ARRAY OF STRUCTURAL ELEMENTS, BODY STATION 1040

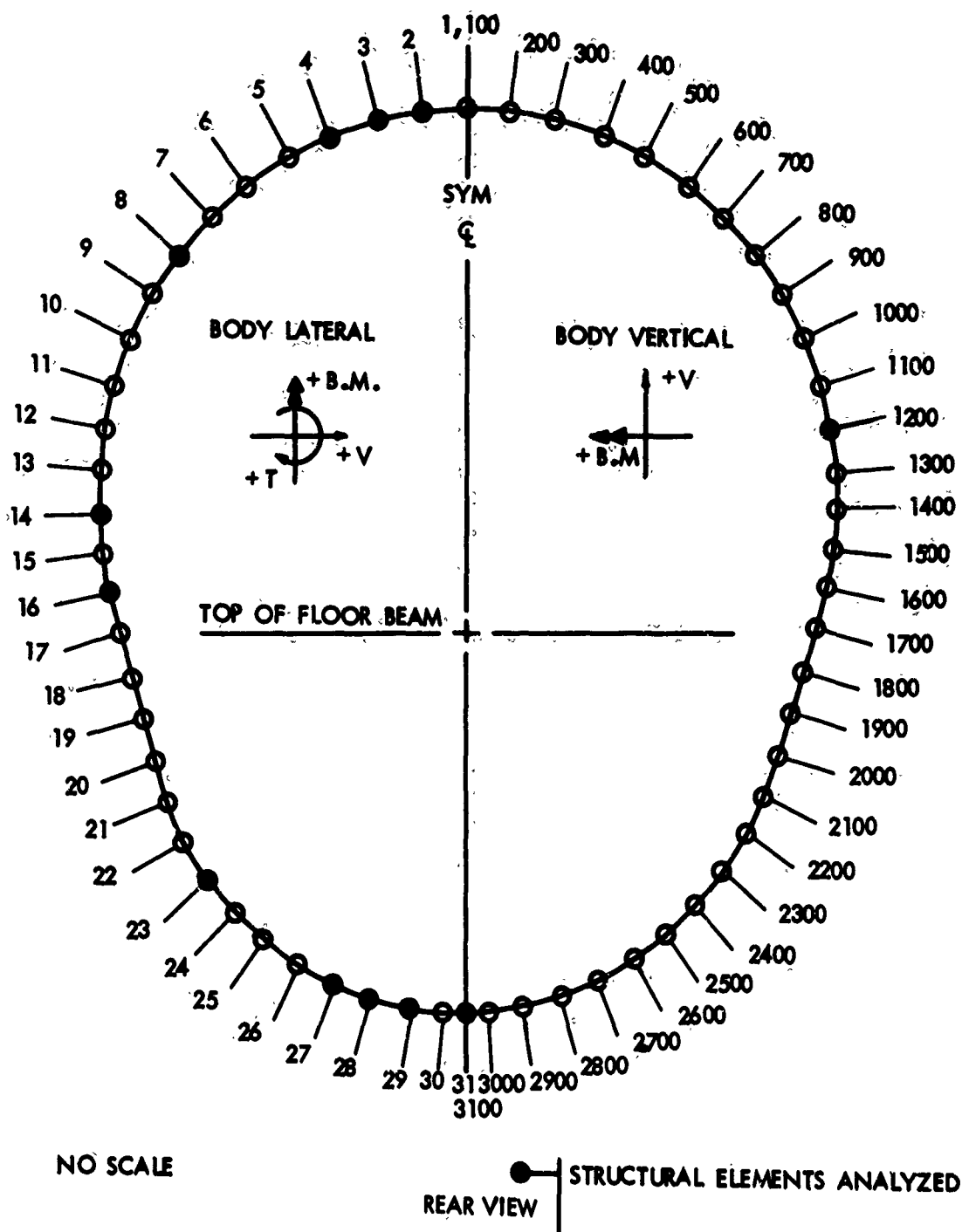
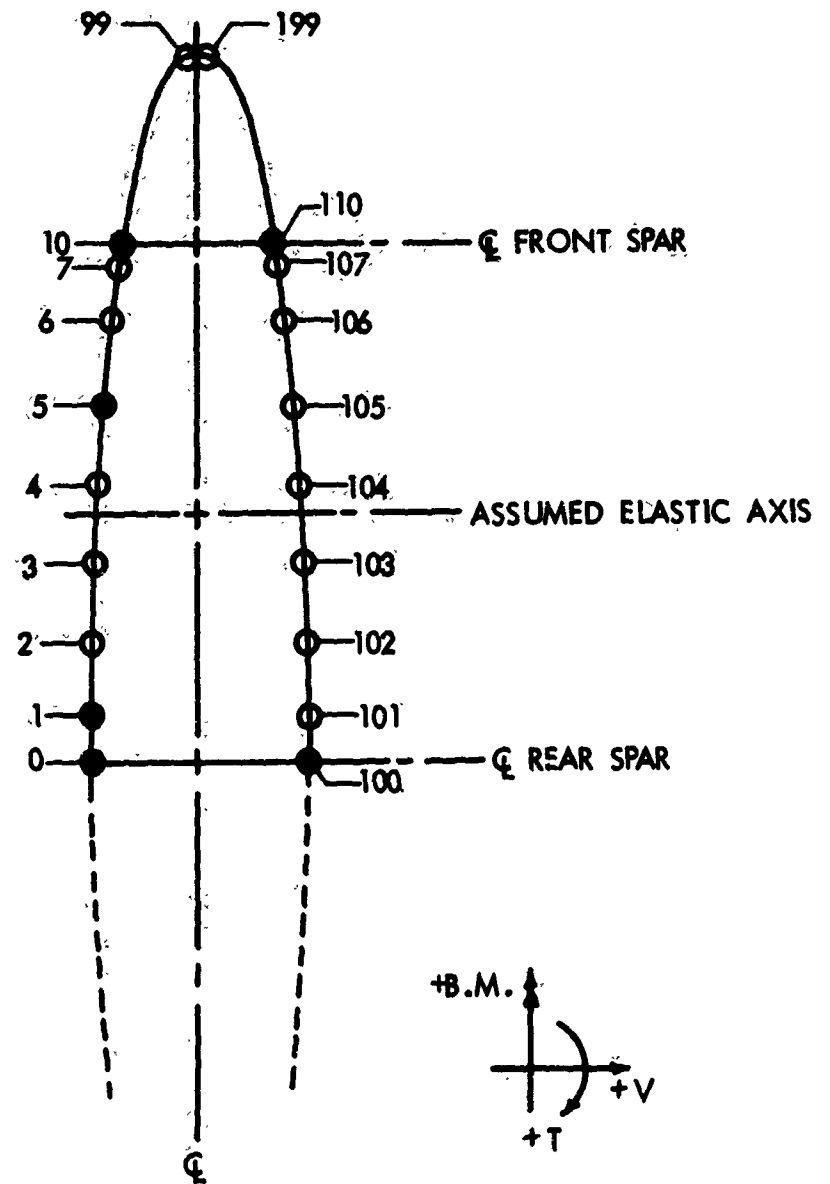


FIGURE 69 (c). ARRAY OF STRUCTURAL ELEMENTS, BODY STATION 1360



AIRPLANE  
PLAN VIEW

● | STRUCTURAL  
ELEMENTS  
ANALYZED

NO SCALE

FIGURE 70. ARRAY OF STRUCTURAL ELEMENTS, FIN ELASTIC AXIS  
STATION 158

TABLE 10a. RMS STRESS AND ZERO CROSSINGS

7200 CONDITION 24C VERTICAL GUST ANALYSIS  
WING STA STATION=0.33

| ELEMENT NO. | 7200 CROSSINGS PER CY |            |            |          |
|-------------|-----------------------|------------|------------|----------|
|             | MEAN STRESS           | MIN STRESS | MAX STRESS | STRESS   |
| 0           | 30.3210               | 100.7079   | 197.9920   | 0.001000 |
| 1           | 40.8127               | 176.3221   | 100.7345   | 0.001000 |
| 2           | 40.7610               | 104.3030   | 100.7610   | 0.001000 |
| 3           | 41.7377               | 197.3093   | 100.6620   | 0.001000 |
| 4           | 37.9697               | 205.7031   | 100.6620   | 0.001000 |
| 5           | 40.1107               | 213.6740   | 207.6770   | 0.001000 |
| 6           | 43.4354               | 218.2010   | 213.6642   | 0.001000 |
| 7           | 45.4972               | 222.2780   | 218.3067   | 0.001000 |
| 8           | 50.4277               | 223.1722   | 217.6167   | 0.001000 |
| 9           | 62.2244               | 222.3742   | 215.0076   | 0.001000 |
| 10          | 67.0954               | 220.1669   | 212.0796   | 0.001000 |
| 11          | 71.5464               | 216.3543   | 210.0245   | 0.001000 |
| 12          | 75.0760               | 200.0701   | 203.0520   | 0.001000 |
| 13          | 80.1550               | 202.6647   | 194.0344   | 0.001000 |
| 14          | 100.5316              | 194.0499   | 184.1700   | 0.001000 |
| 15          | 104.7715              | 184.0110   | 177.0000   | 0.001000 |
| 16          | 112.5317              | 173.0222   | 167.0234   | 0.001000 |
| 17          | 116.0767              | 161.8132   | 154.7603   | 0.001000 |
| 18          | 101.5398              | 130.4300   | 141.5567   | 0.001000 |
| 19          | 105.1413              | 113.5387   | 106.5507   | 0.001000 |
| 20          | 123.0400              | 143.2230   | 136.2711   | 0.001000 |
| 21          | 125.0072              | 155.2603   | 144.7677   | 0.001000 |
| 22          | 129.0024              | 165.4566   | 155.7021   | 0.001000 |
| 23          | 117.3044              | 175.1706   | 165.0150   | 0.001000 |
| 24          | 157.5290              | 183.2043   | 173.0407   | 0.001000 |
| 25          | 104.0224              | 160.2203   | 161.7234   | 0.001000 |
| 26          | 73.1244               | 193.0923   | 164.5491   | 0.001000 |
| 27          | 69.2328               | 200.7206   | 160.3742   | 0.001000 |
| 28          | 61.3725               | 204.7640   | 167.0191   | 0.001000 |
| 29          | 61.3725               | 207.1770   | 194.7646   | 0.001000 |
| 30          | 57.0234               | 200.0047   | 200.3133   | 0.001000 |
| 31          | 52.0040               | 209.1440   | 200.5540   | 0.001000 |
| 32          | 47.5495               | 204.2134   | 194.3210   | 0.001000 |
| 33          | 45.2213               | 205.0341   | 197.0277   | 0.001000 |
| 34          | 42.4499               | 202.4500   | 193.0637   | 0.001000 |
| 35          | 40.5093               | 197.0750   | 180.2643   | 0.001000 |
| 36          | 36.0344               | 191.0310   | 183.0000   | 0.001000 |
| 37          | 37.5377               | 193.0703   | 175.3420   | 0.001000 |
| 38          | 34.7272               | 175.3414   | 164.5744   | 0.001000 |
| 39          | 34.2144               | 165.7705   | 157.2070   | 0.001000 |
| 40          | 34.0174               | 155.5493   | 157.0670   | 0.001000 |
| 41          | 34.0174               | 144.0020   | 136.0320   | 0.001000 |
| 42          | 20.0451               | 132.3000   | 134.1004   | 0.001000 |

TABLE 10b. CORRELATION COEFFICIENTS AND STRESS RATES

7200 COMPRESSION 20C VERTICAL GUST ANALYSIS  
WIND STA STATION=33

| ELEMENT NO. | CORRELATION<br>COEFFICIENT | SEIN     | SEIN     | SEIN     |
|-------------|----------------------------|----------|----------|----------|
| 0           | -0.015000                  | 0.720000 | 1.567705 | 1.670000 |
| 1           | -0.007100                  | 0.000000 | 1.557102 | 1.557102 |
| 2           | -0.300125                  | 0.001000 | 1.732700 | 1.557102 |
| 3           | -0.370010                  | 0.010000 | 1.051700 | 1.701000 |
| 4           | -0.350076                  | 0.000000 | 1.033000 | 1.033000 |
| 5           | -0.327100                  | 0.000000 | 2.000000 | 1.033000 |
| 6           | -0.200000                  | 0.000000 | 2.000000 | 2.000000 |
| 7           | -0.271000                  | 0.010000 | 2.000000 | 2.000000 |
| 8           | -0.110000                  | 0.000000 | 2.000000 | 2.000000 |
| 9           | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 10          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 11          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 12          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 13          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 14          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 15          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 16          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 17          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 18          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 19          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 20          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 21          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 22          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 23          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 24          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 25          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 26          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 27          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 28          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 29          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 30          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 31          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 32          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 33          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 34          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 35          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 36          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 37          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 38          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 39          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 40          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 41          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 42          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 43          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 44          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 45          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 46          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 47          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 48          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 49          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |
| 50          | -0.100000                  | 0.000000 | 2.000000 | 2.000000 |

skin, and segment stress levels,  $\bar{A}$ , are given in Table 10(a) with their associated number of zero crossings. Table 10(b) contains the correlation coefficients between the shear and axial stresses and the respective stress rates. Similar values were calculated for all the structural elements indicated in Figs. 68 through 70.

### Results - Statistical Analysis

Following the procedure outlined in the Analysis section, the rms stresses, correlation coefficients, and stress rates were used to determine the probability of exceeding limit strength,  $P(MS < 0, \sigma_w)$ , and the number of times per hour that the limit strength envelope is penetrated. The resultant probabilities,  $P(MS < 0, \sigma_w)$ , are given in Table 11 for Structural Element 9, Condition 24C. The probability,  $P(MS < 0, \sigma_w)$ , for all the structural elements analyzed by the design envelope approach were plotted and are shown in Figs. 71(a) through 74(d). The most critical element for each profile condition, i.e., the element which demonstrates the highest probability of exceeding limit strength, was selected using the techniques described on Page 58. The values resulting from the multiplication of these critical  $P(MS < 0, \sigma_w)$  with  $\hat{f}(\sigma_w)$  are shown in Figs. 75 through 78. The maximum values of these overall probability curves were used with the curves of  $P(\Delta n > \Delta n_d) \hat{f}(\sigma_w)$  in Figs. 79 and 80 to determine the design incremental cg acceleration. The design levels of  $\sigma_w \eta_d$  and  $\sigma_v \eta_d$  were then calculated and appear in Table 12. Corresponding exceedance ratios as determined by Eq. (15) are also given in Table 12.

The altitude variation of  $\sigma_w \eta_d$  determined by the joint probability method is shown in Fig. 81 for Wing Eta Station .33 and for the vertical tail E. A. Station 158. Similar information is given in Fig. 82.

The altitude trends obtained by the joint probability approach indicate that the critical altitude of 23,500 ft. for the lateral analyses and 22,000 ft. for the vertical analyses as chosen by the bending moment criteria were correct.

The variation of  $\sigma_w \eta_d$  around the wing structural box at Wing Eta Station .33, Condition 24C, as determined by the joint probability method, is shown in Fig. 83. The static margin of safety for each element as obtained by the static stress analysis (12) for a high bending moment condition is also shown in Fig. 83. The comparison indicates that the strength capability as determined by the statistical approach exhibits the same trend as the static margin of safety. There is, however, a difference in which element is most critical. Element 9 and the lower surface has the lowest margin of safety while Elements 117 and 122 on the upper surface display the lowest  $\sigma_w \eta_d$ . The significance of this

TABLE 11. VALUES OF  $P(MS^{-1}) f(\sigma_w)$

|                                           |                                                      |                      |               |
|-------------------------------------------|------------------------------------------------------|----------------------|---------------|
| 7204 CONDITION 24C VERTICAL GUST ANALYSIS |                                                      |                      |               |
| WING FTA STATION = 0.33                   |                                                      | STRUCTURAL ELEMENT 9 |               |
| TURBULENCE PARAMETERS                     |                                                      |                      |               |
| P1 = 0.032000                             |                                                      |                      |               |
| P2 = 0.000125                             |                                                      |                      |               |
| R1 = 3.200000                             |                                                      |                      |               |
| R2 = 11.700000                            |                                                      |                      |               |
| IG STRESSES (PSI)                         |                                                      |                      |               |
| SHFAP                                     | SKRN                                                 | SEGMENT              |               |
| -2240.0                                   | 12221.0                                              | 12498.0              |               |
| V TRUE (FT/SEC) = 410.7                   |                                                      |                      |               |
| RMS<br>GUST VELOCITY<br>(FT/SEC)          | PROBABILITY OF<br>EXCEEDING LIMIT<br>DESIGN STRENGTH | F (SIGW)             | P X F (SIGW)  |
| 28.                                       | 0.                                                   | 0.4864215E-06        | 0.            |
| 29.                                       | 0.                                                   | 0.3949974E-06        | 0.            |
| 30.                                       | 0.                                                   | 0.3184271E-06        | 0.            |
| 31.                                       | 0.00005                                              | 0.2548235E-06        | 0.1392634E-10 |
| 32.                                       | 0.00014                                              | 0.2074437E-06        | 0.2825186E-10 |
| 33.                                       | 0.00025                                              | 0.1576593E-06        | 0.3994703E-10 |
| 34.                                       | 0.00039                                              | 0.1250008E-06        | 0.4921112E-10 |
| 35.                                       | 0.00058                                              | 0.9715360E-07        | 0.5611083E-10 |
| 40.                                       | 0.00238                                              | 0.2469449E-07        | 0.5878047E-10 |
| 50.                                       | 0.01313                                              | 0.9274421E-09        | 0.1211255E-10 |
| 60.                                       | 0.03635                                              | 0.1659663E-10        | 0.6032457E-12 |
| 70.                                       | 0.07136                                              | 0.1438279E-12        | 0.1026337E-13 |
| 80.                                       | 0.11497                                              | 0.6003548E-15        | 0.6899351E-16 |
| 90.                                       | 0.16345                                              | 0.1207021E-17        | 0.1972825E-18 |
| 100.                                      | 0.21403                                              | 0.1168864E-20        | 0.2501691E-21 |
| 110.                                      | 0.26467                                              | 0.5451997E-24        | 0.1442718E-24 |
| 120.                                      | 0.31390                                              | 0.1224863E-27        | 0.3844790E-28 |
| 130.                                      | 0.36107                                              | 0.1325448E-31        | 0.4785148E-32 |
| 140.                                      | 0.40553                                              | 0.6908435E-36        | 0.2801543E-36 |
| 150.                                      | 0.44717                                              | 0.                   | 0.            |
| 160.                                      | 0.48588                                              | 0.                   | 0.            |



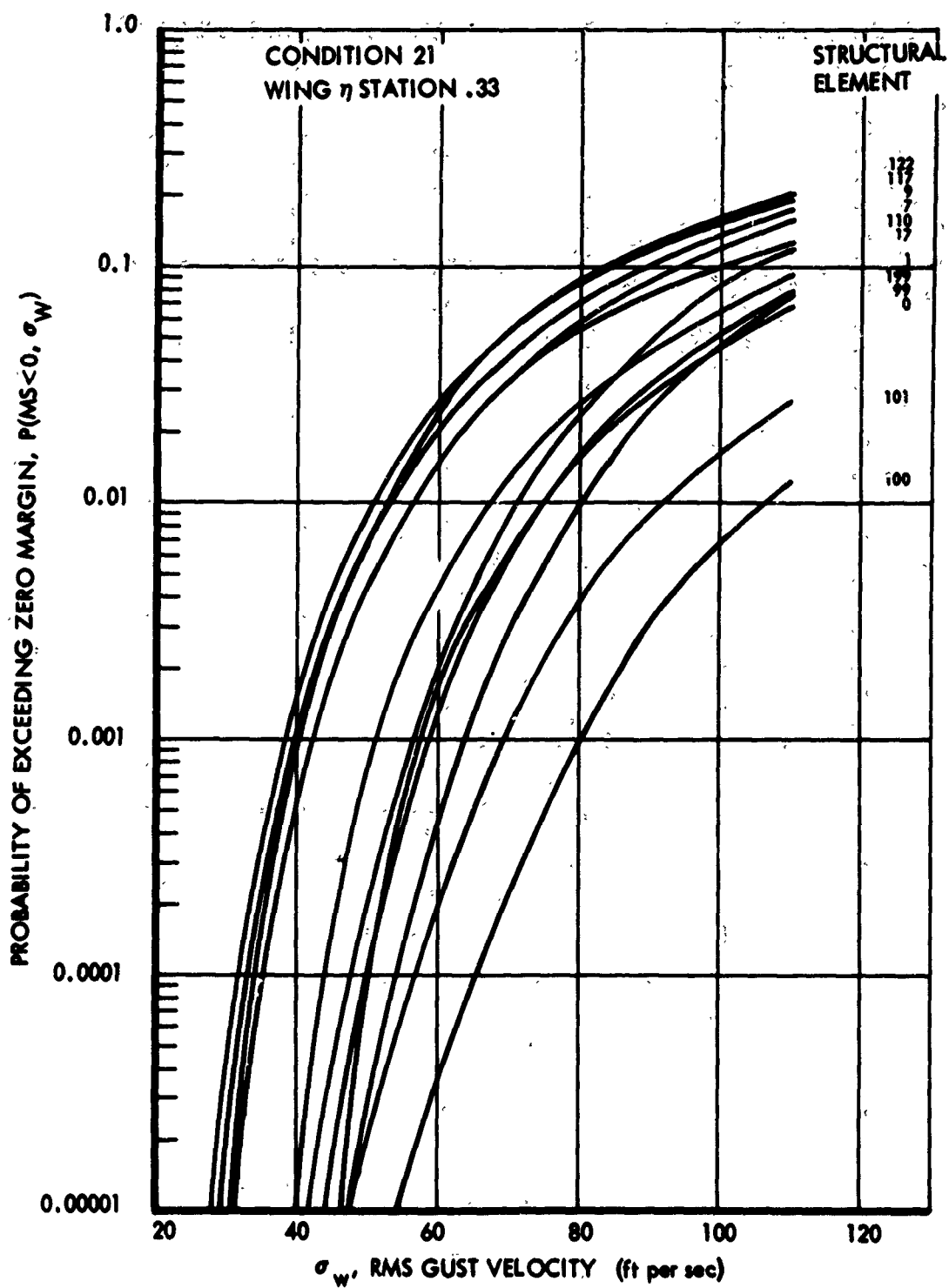


FIGURE 71 (a). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 21

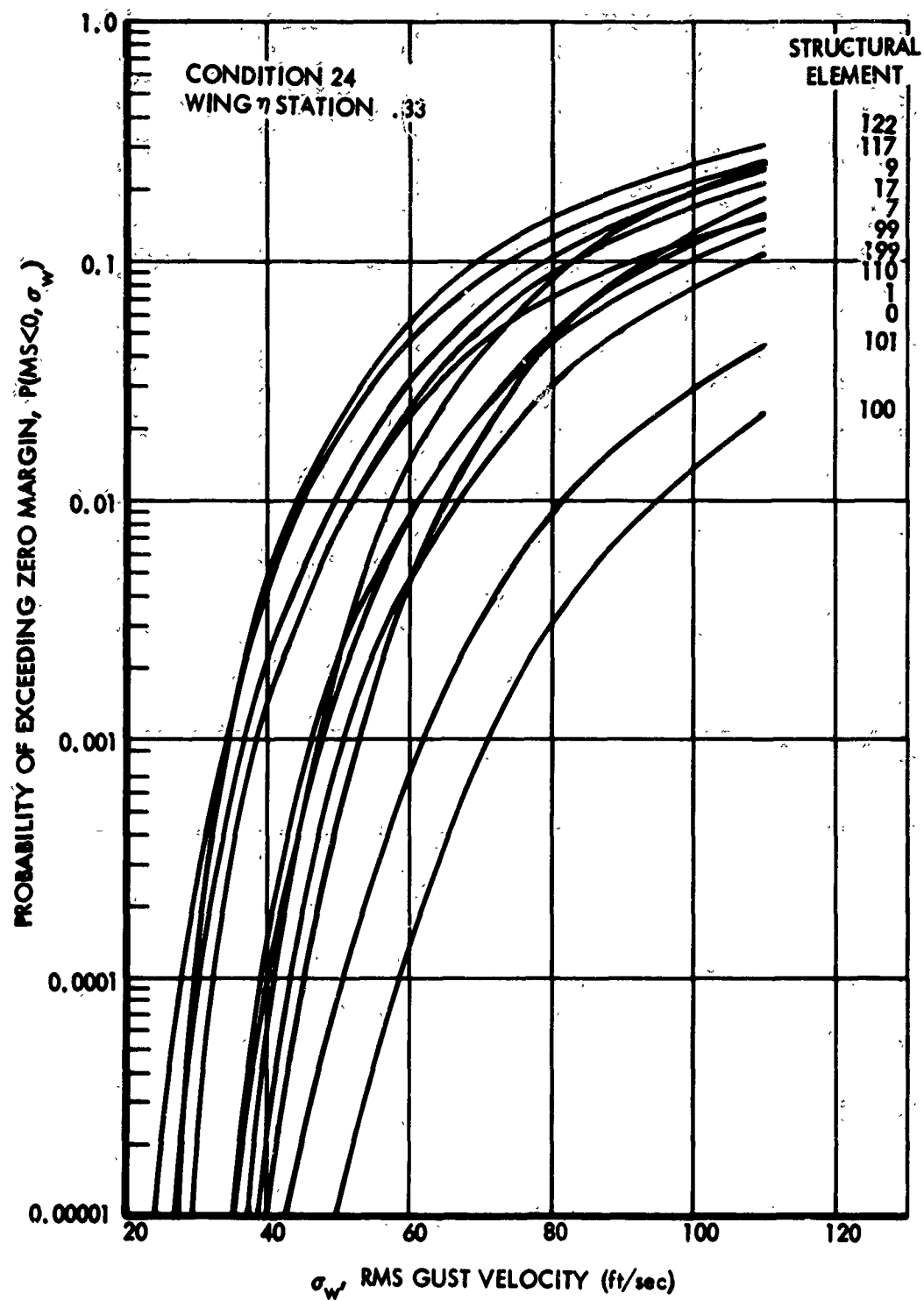


FIGURE 71 (b). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 24

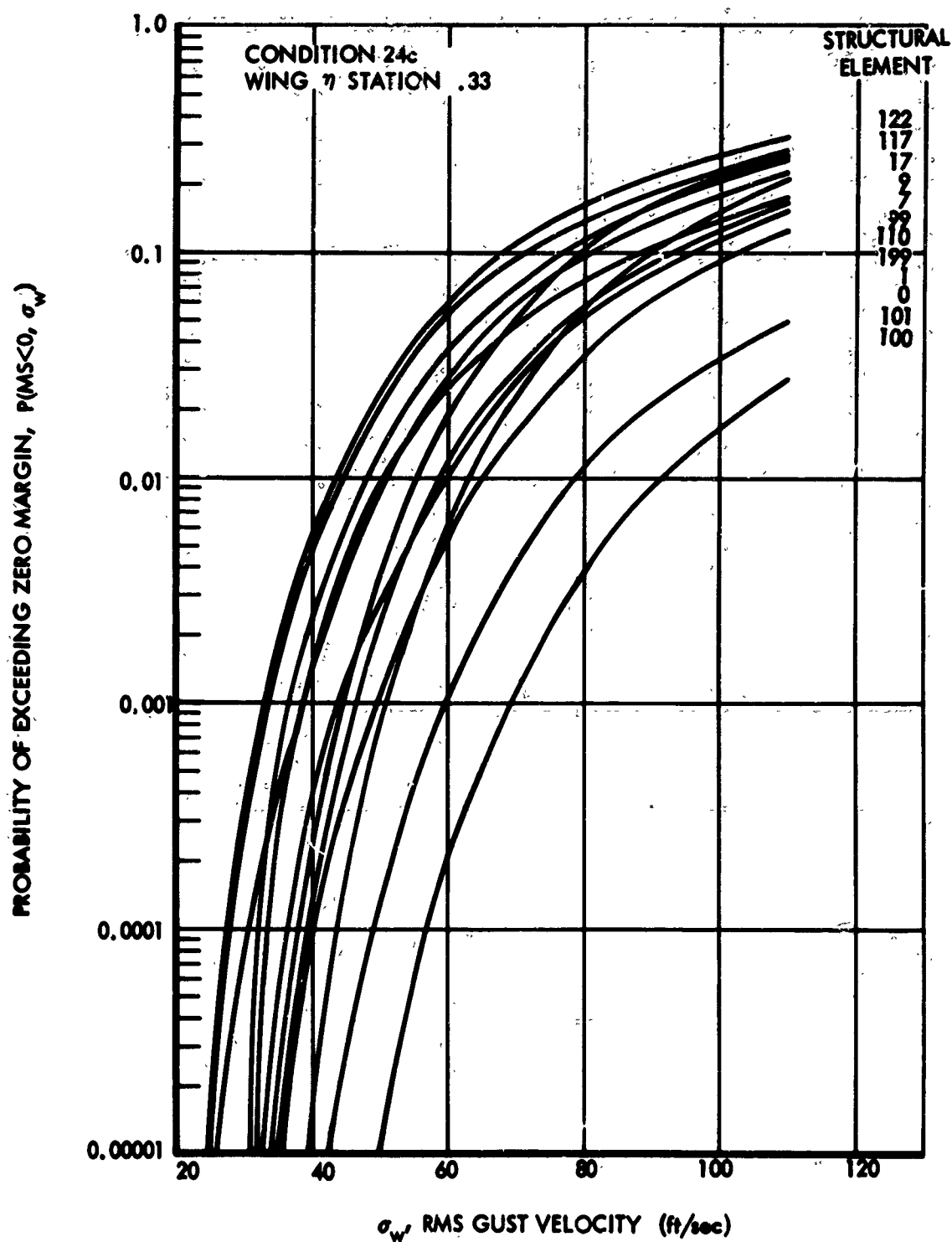


FIGURE 71 (c). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 24C

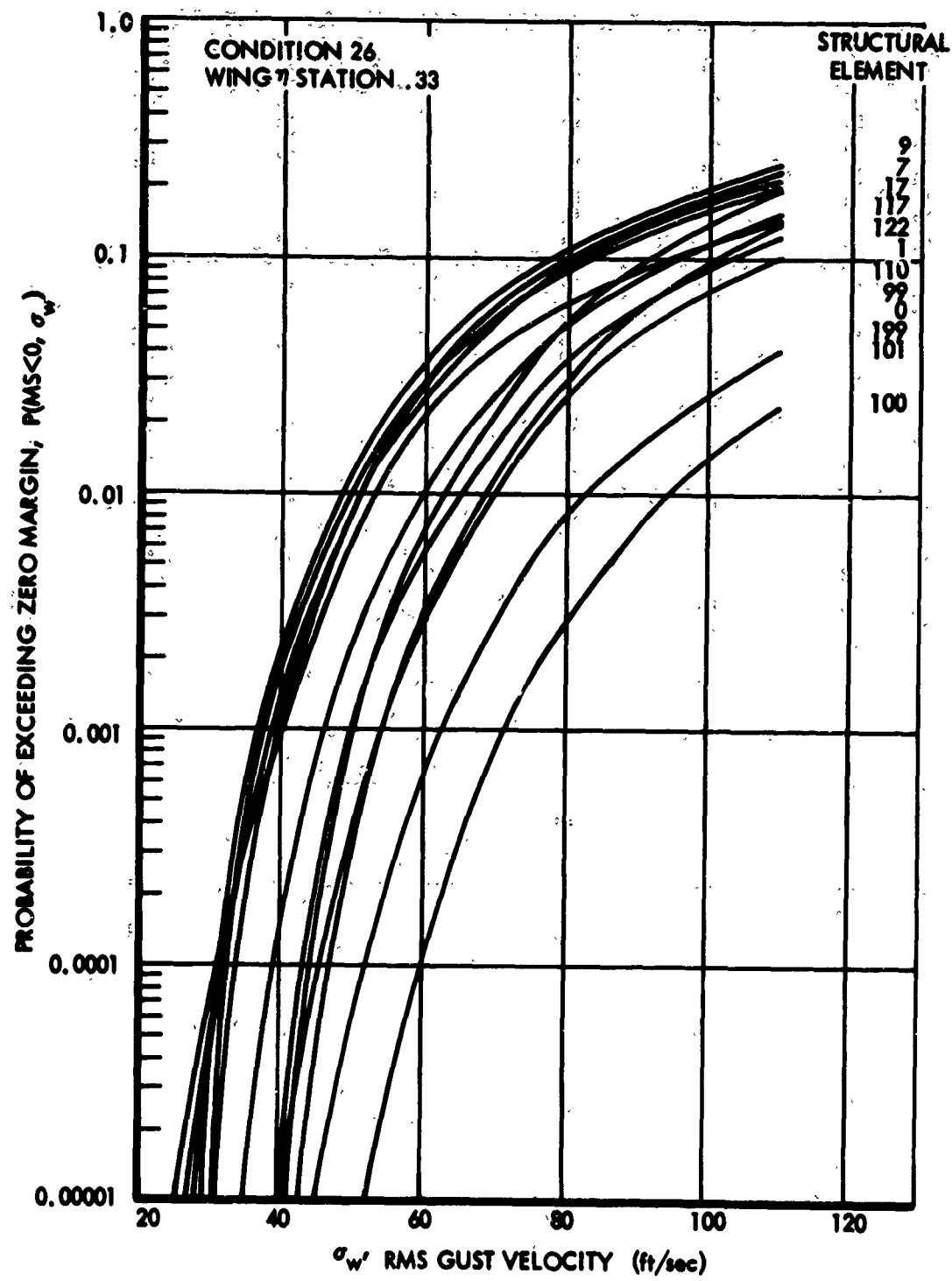


FIGURE 71 (d). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 26

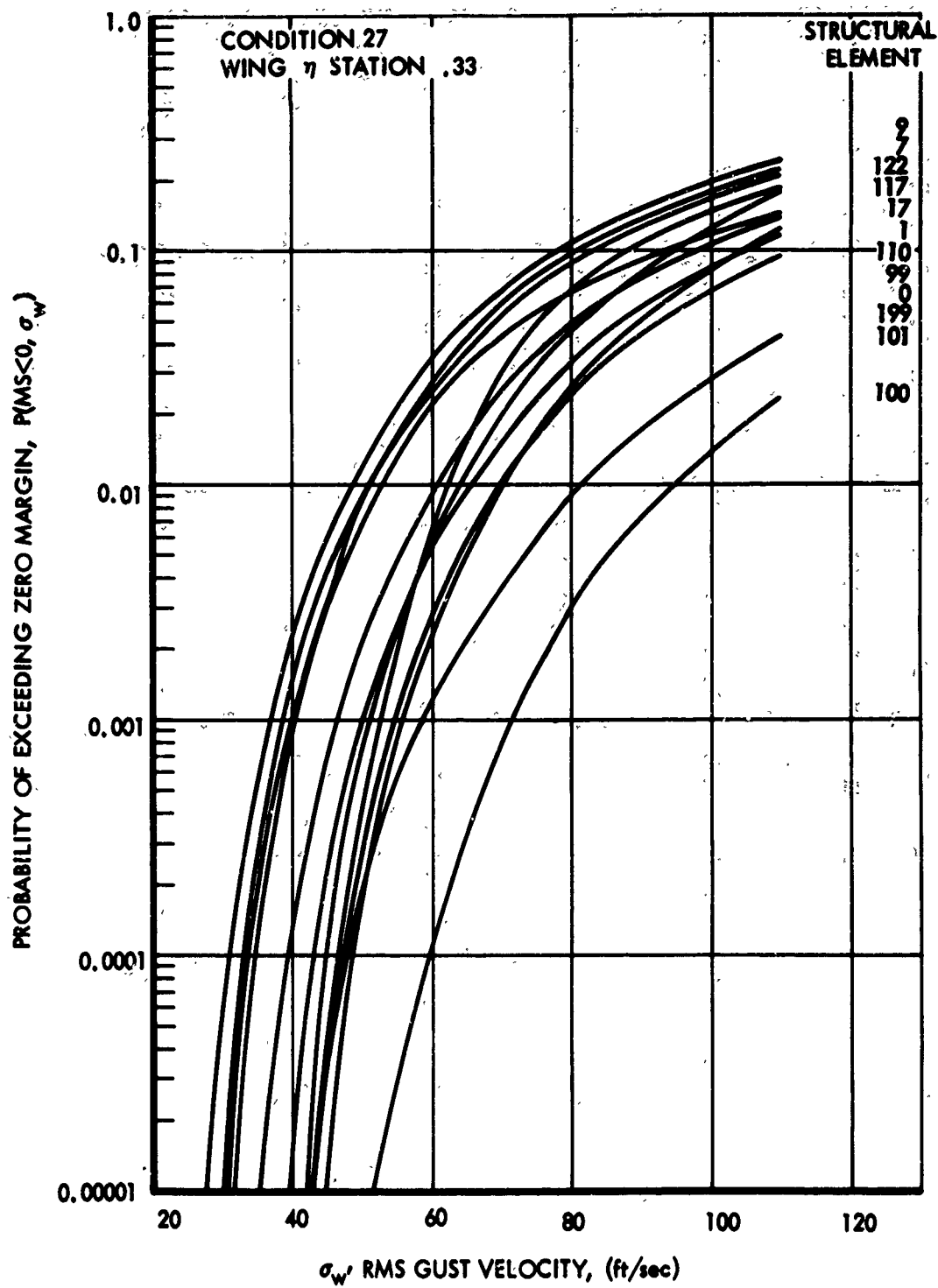


FIGURE 71 (e). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 27

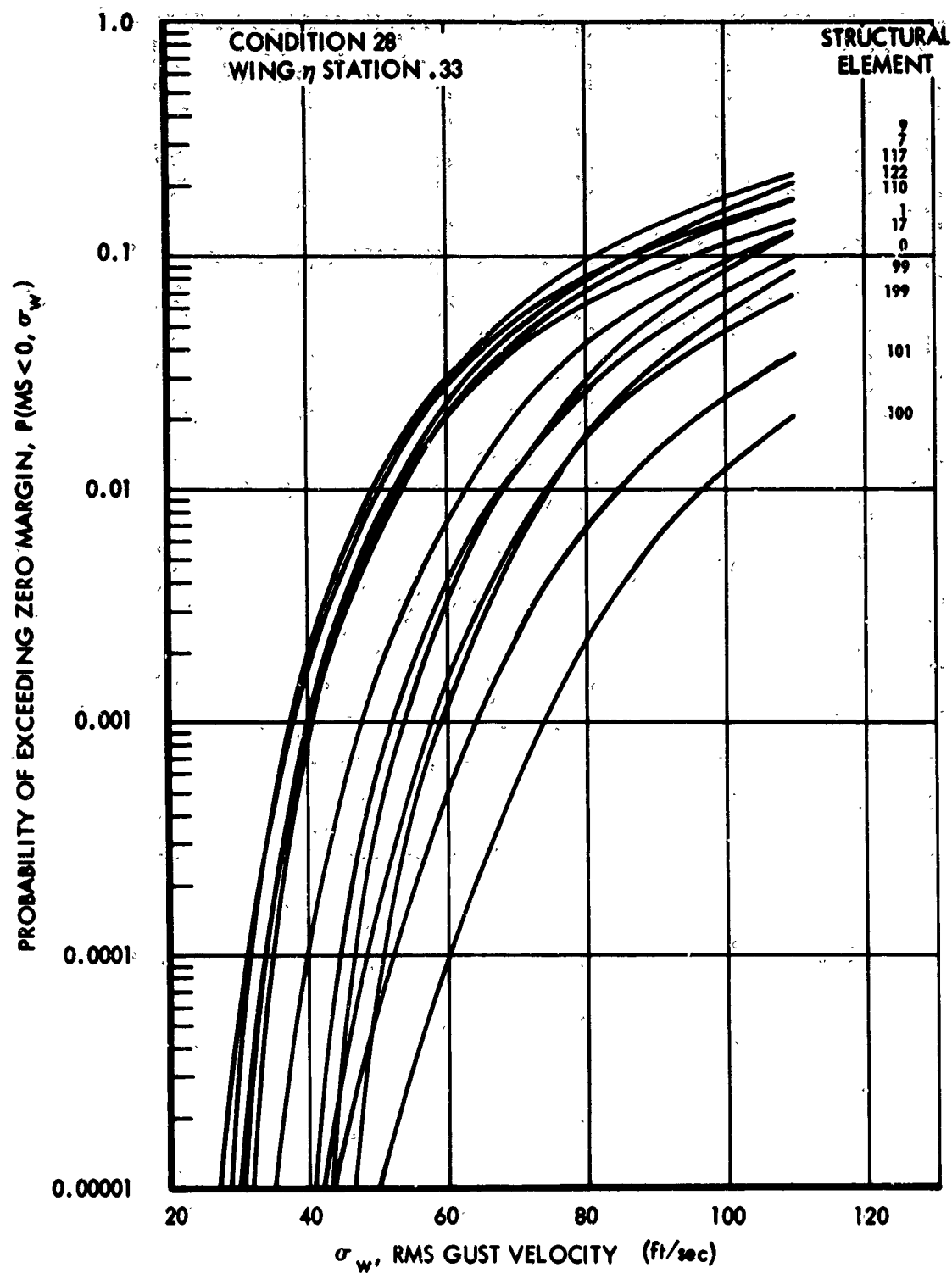


FIGURE 71 (f). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 28

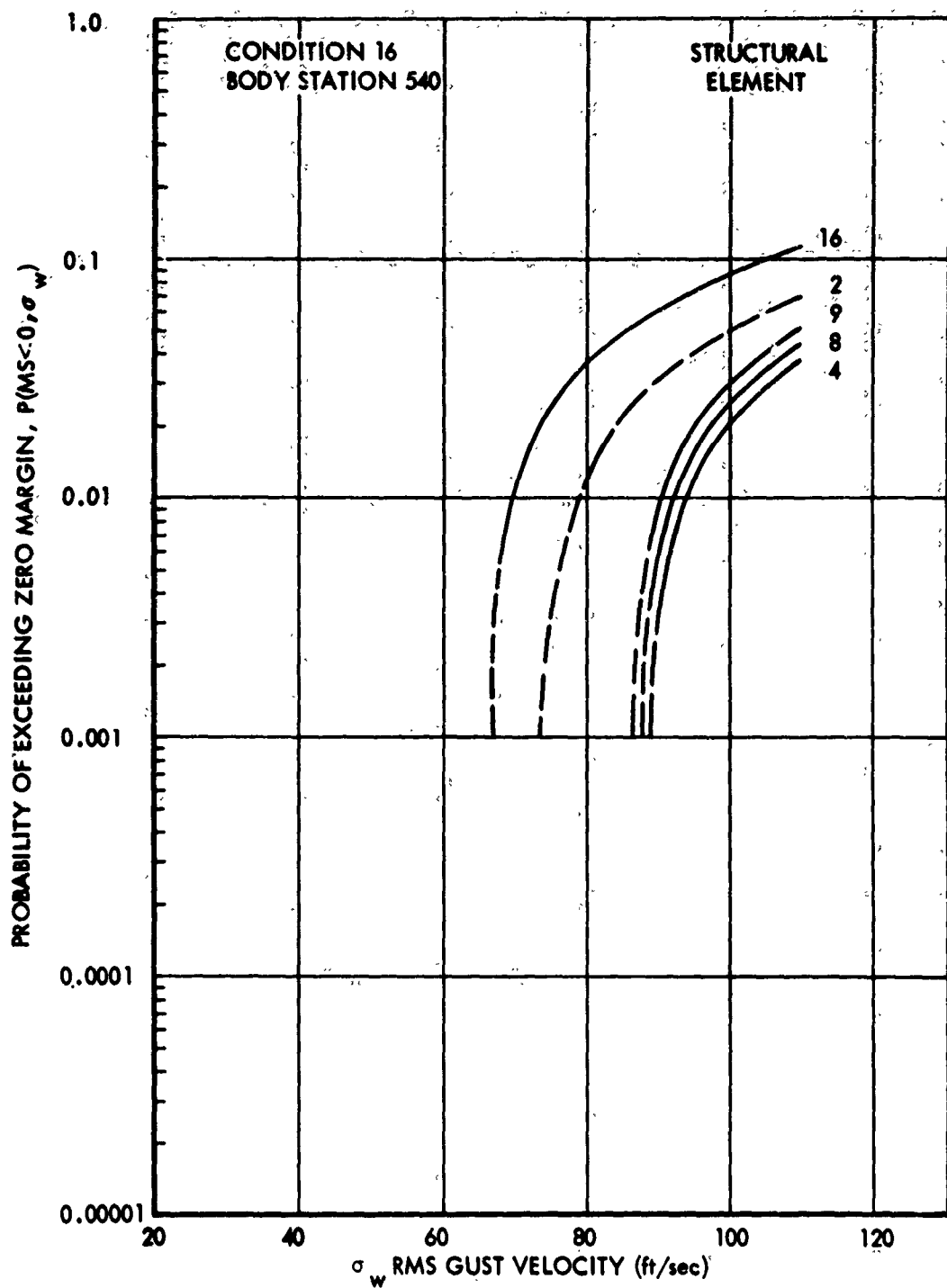


FIGURE 72 (a). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 16

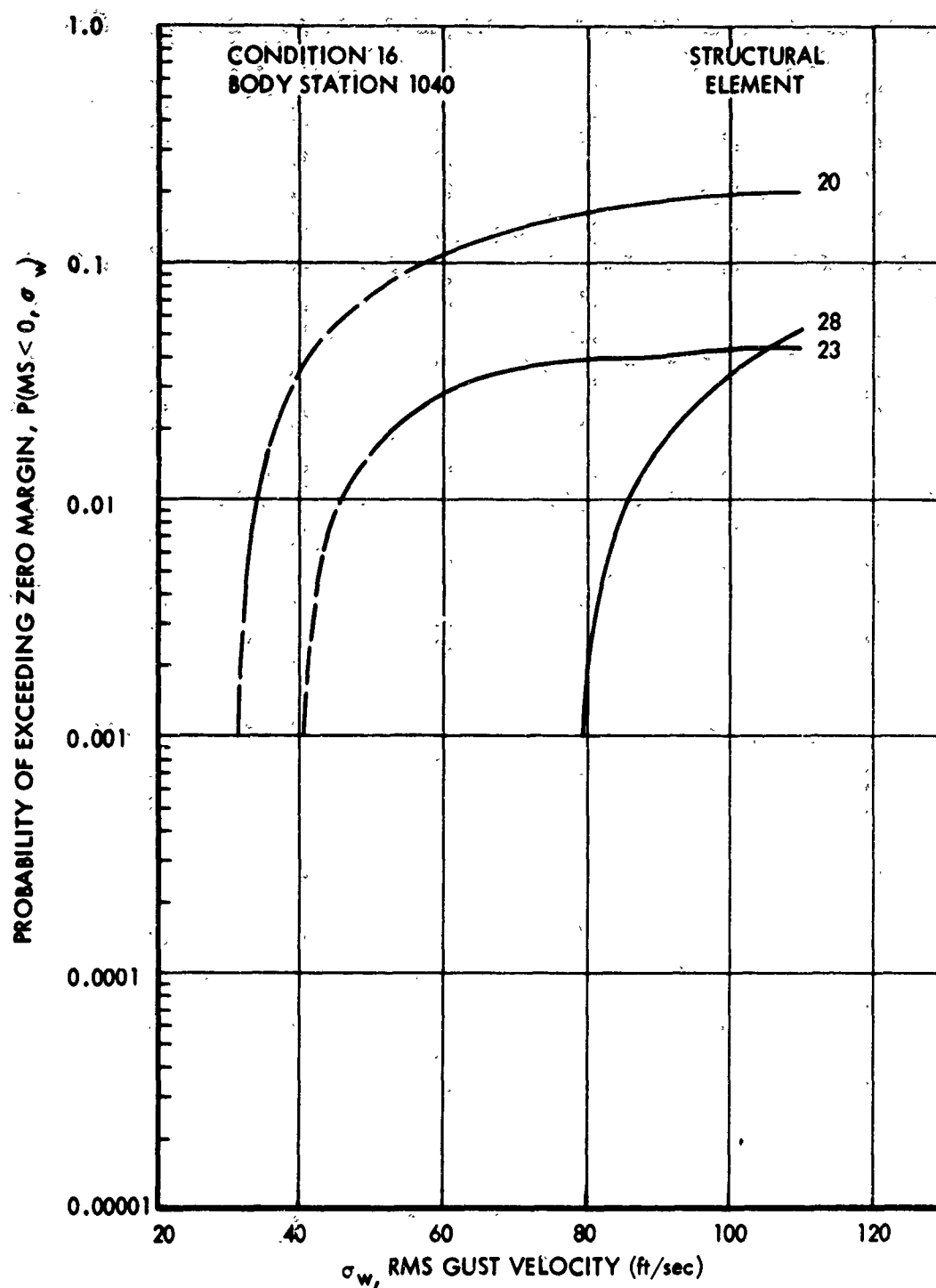


FIGURE 72 (b). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 16



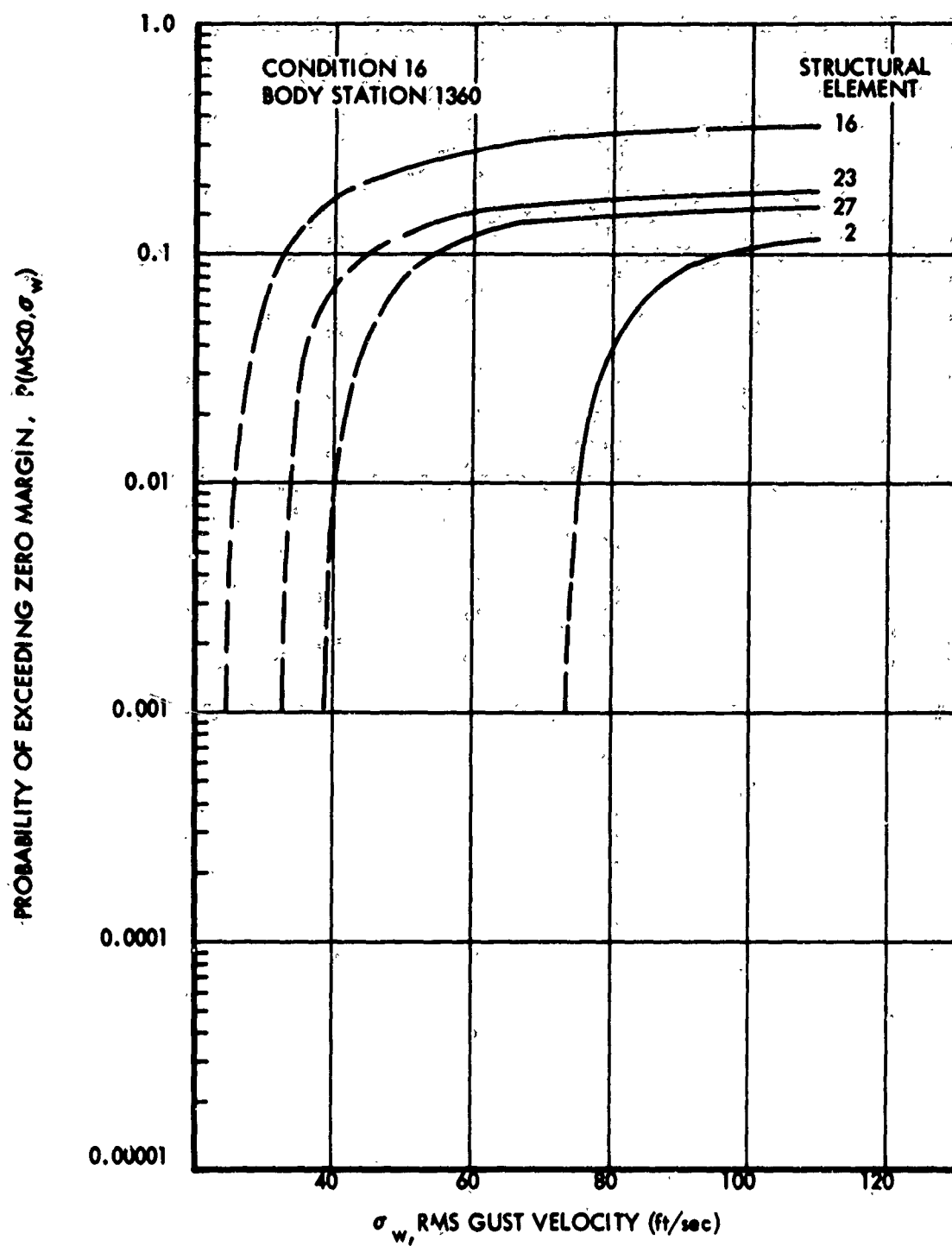


FIGURE 72 (c). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 16

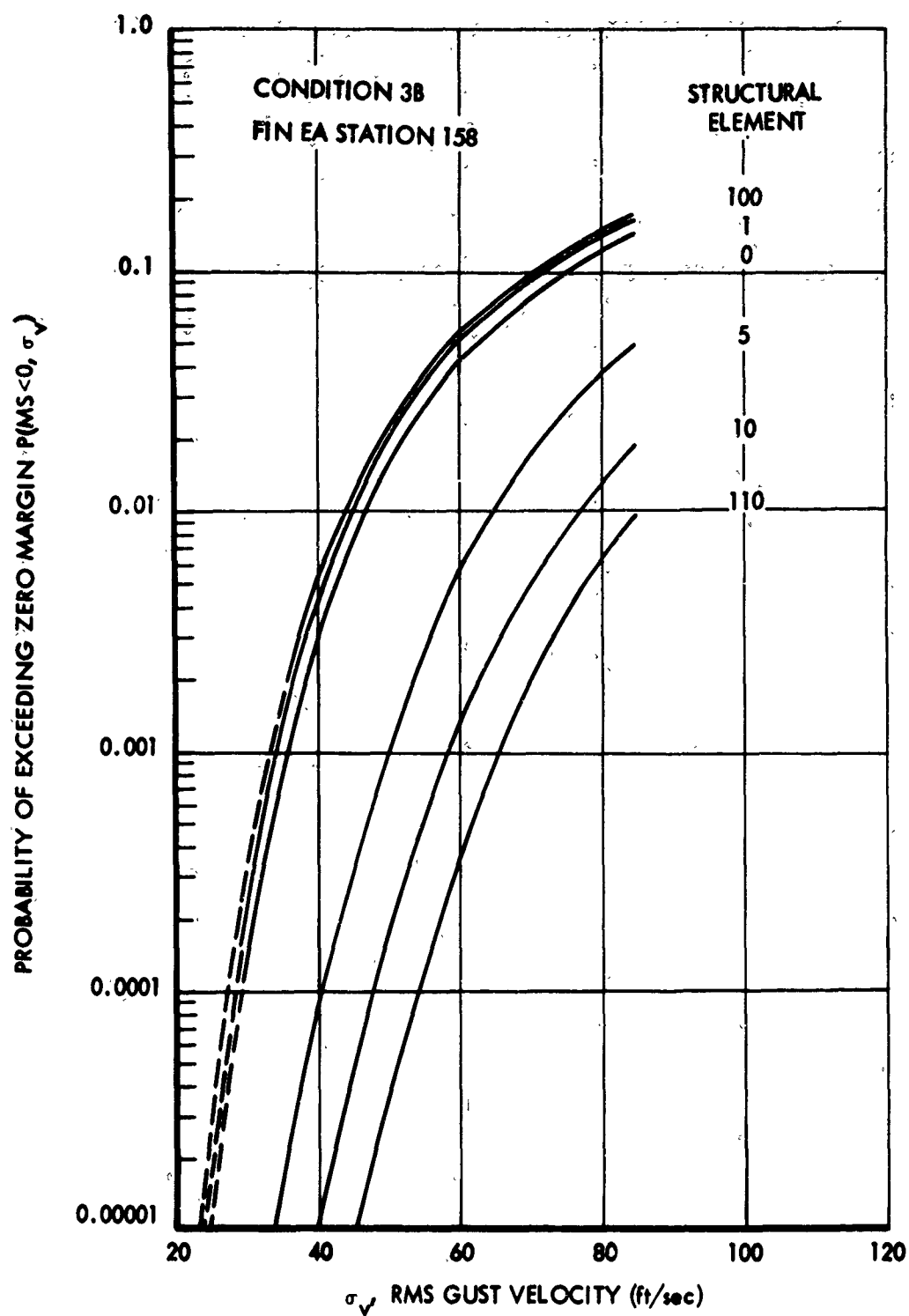


FIGURE 73 (a). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 3B

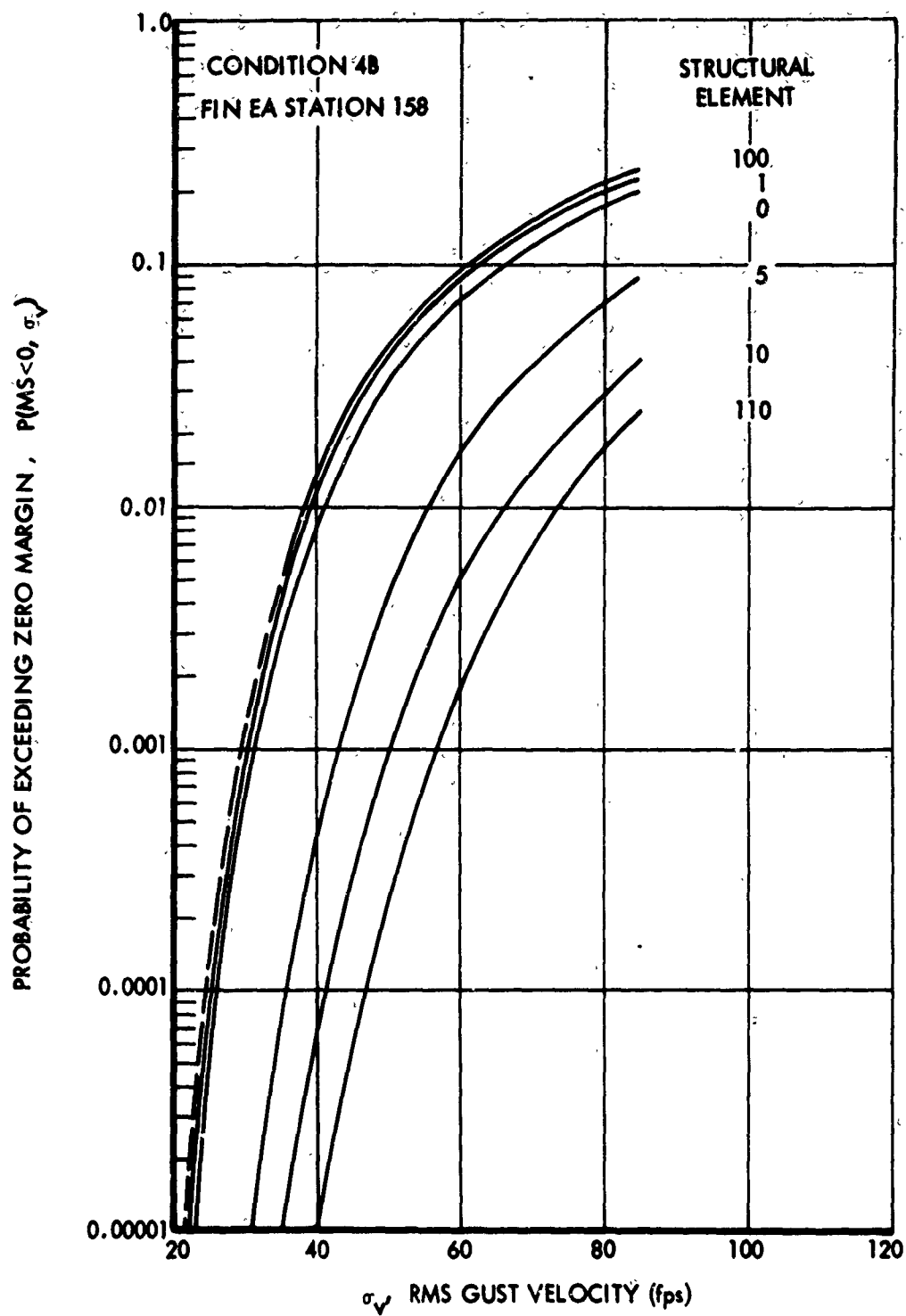


FIGURE 73 (b). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 4B

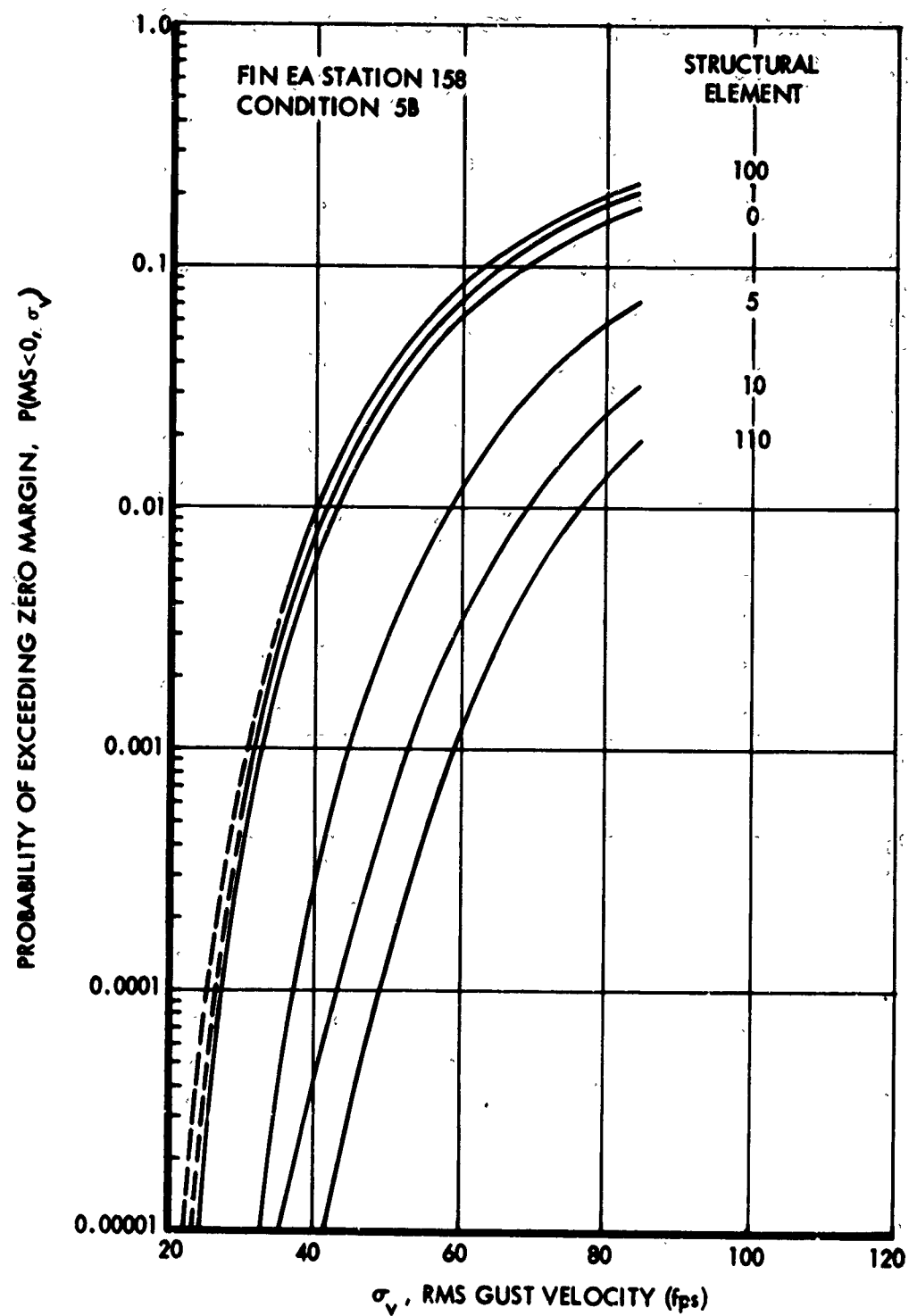


FIGURE 73 (c). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 5B

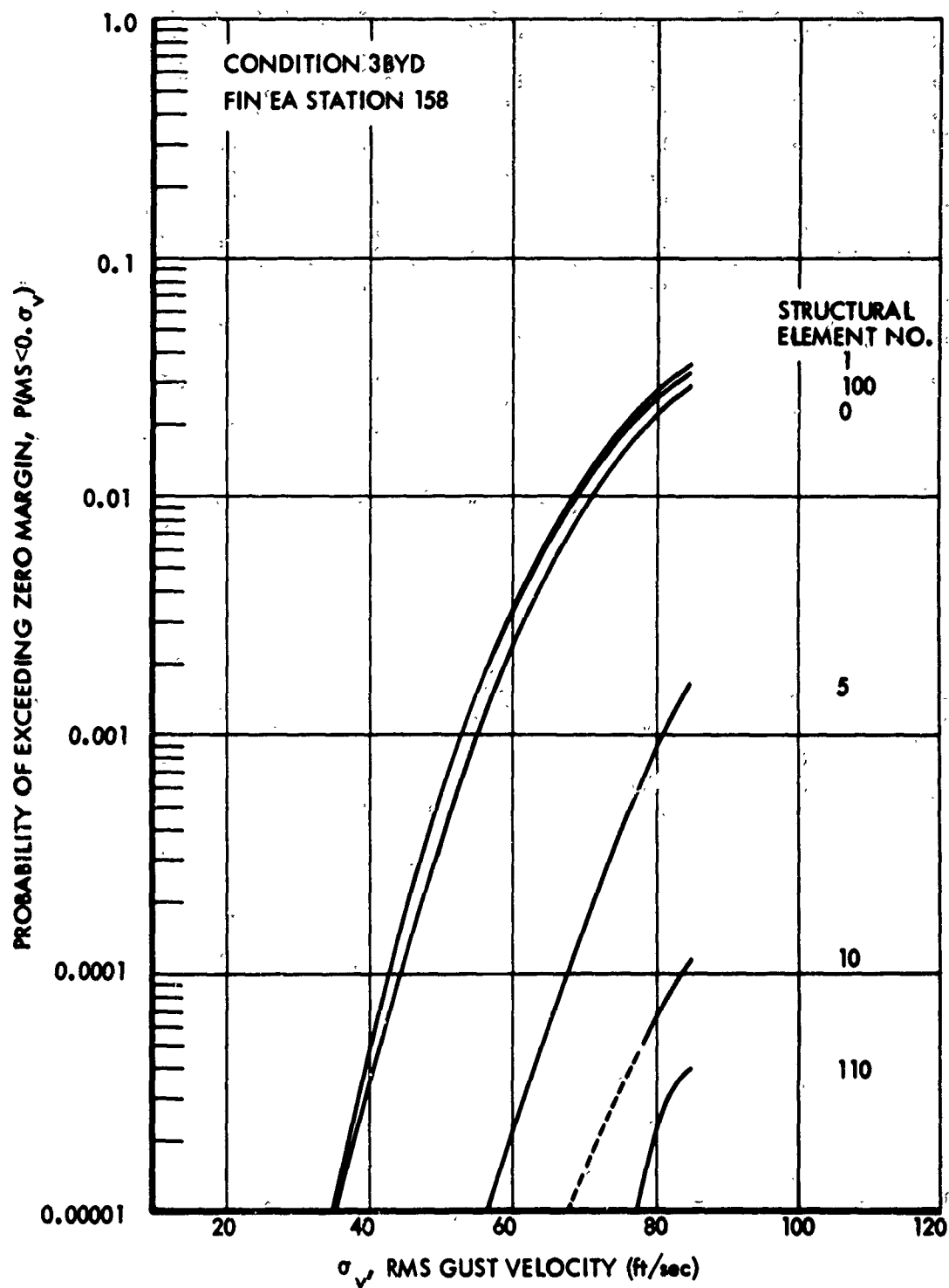


FIGURE 73 (d). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 3BYD

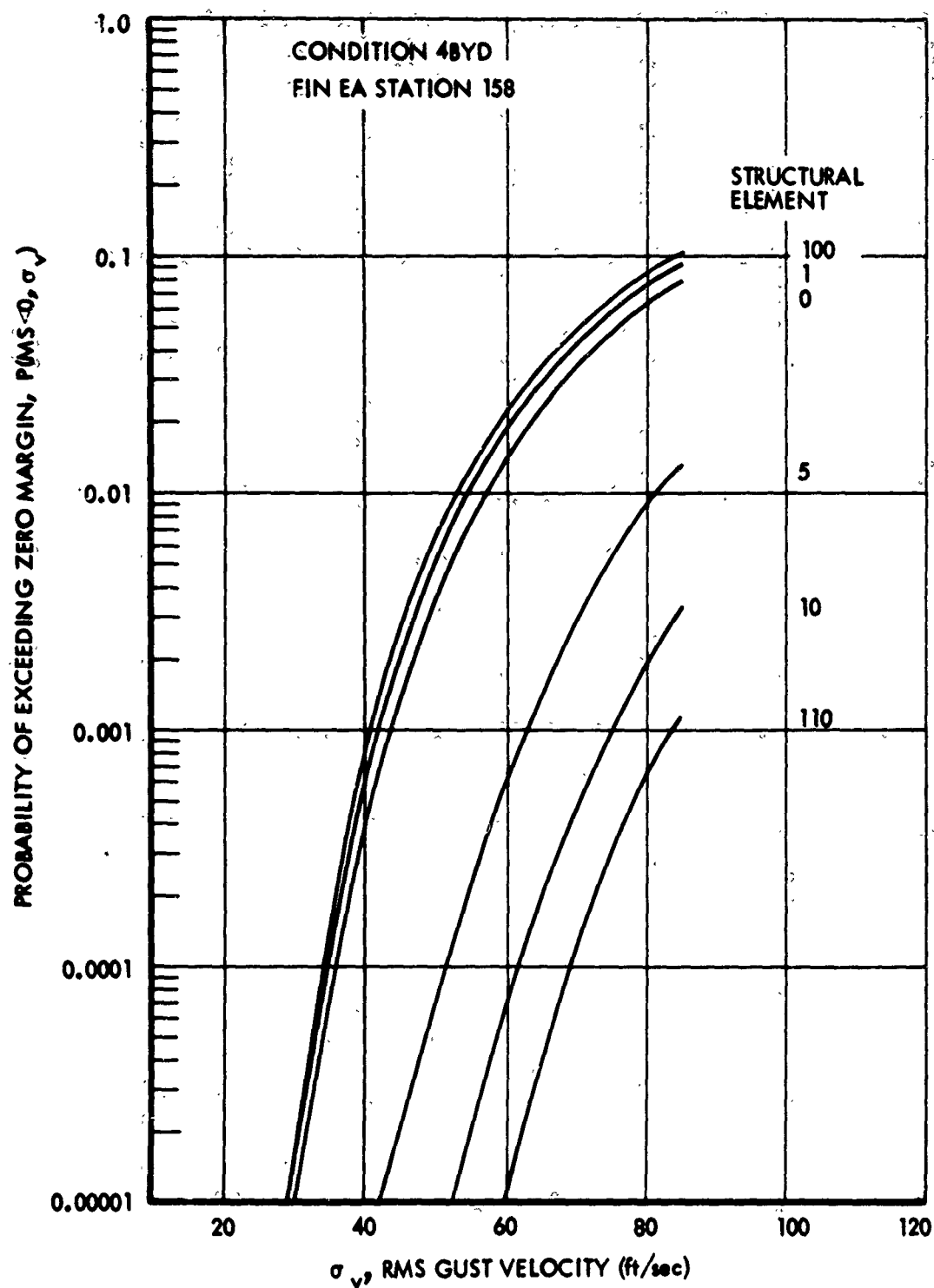


FIGURE 73 (e). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 4BYD

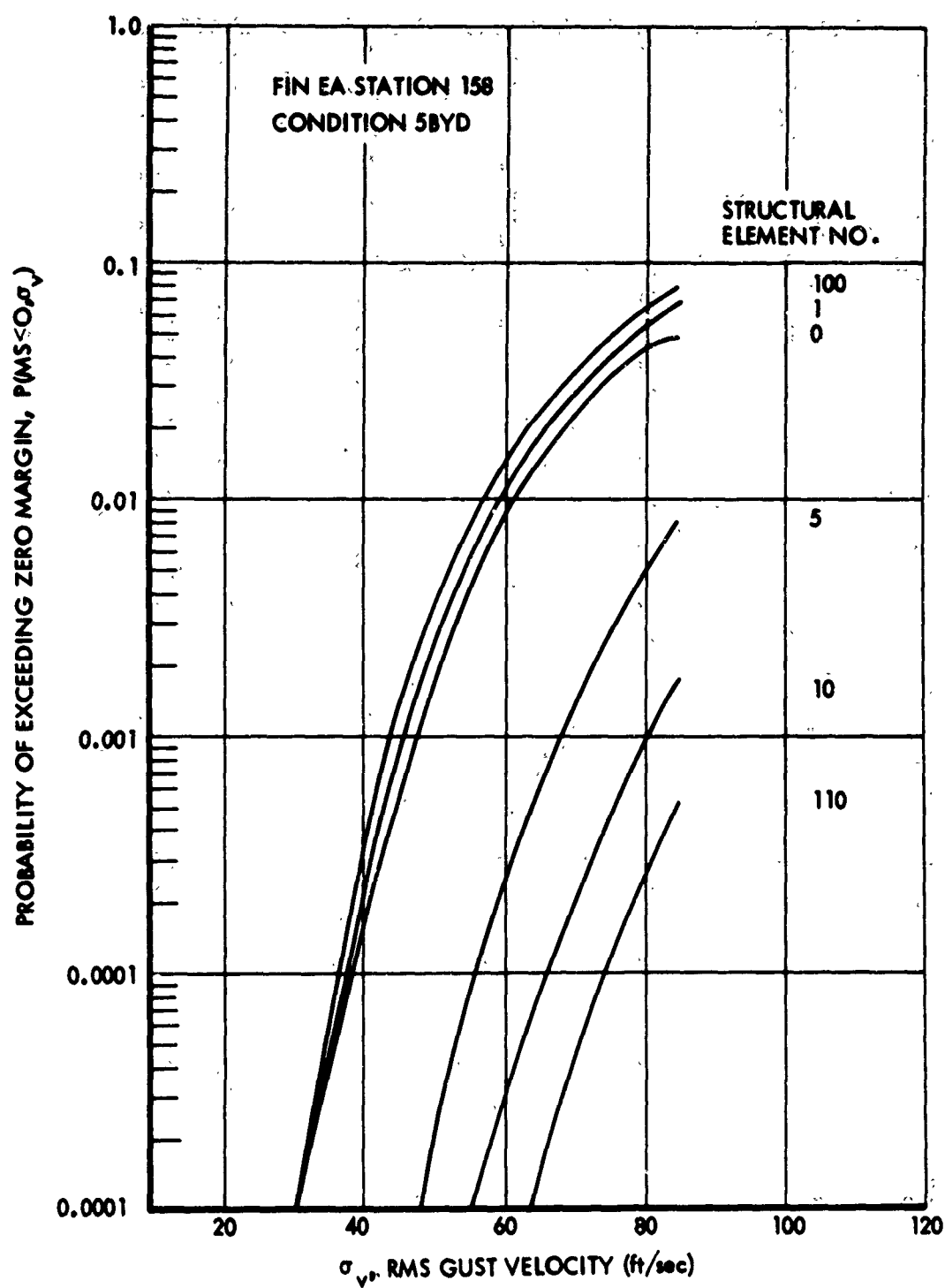


FIGURE 73 (f). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 5BYD

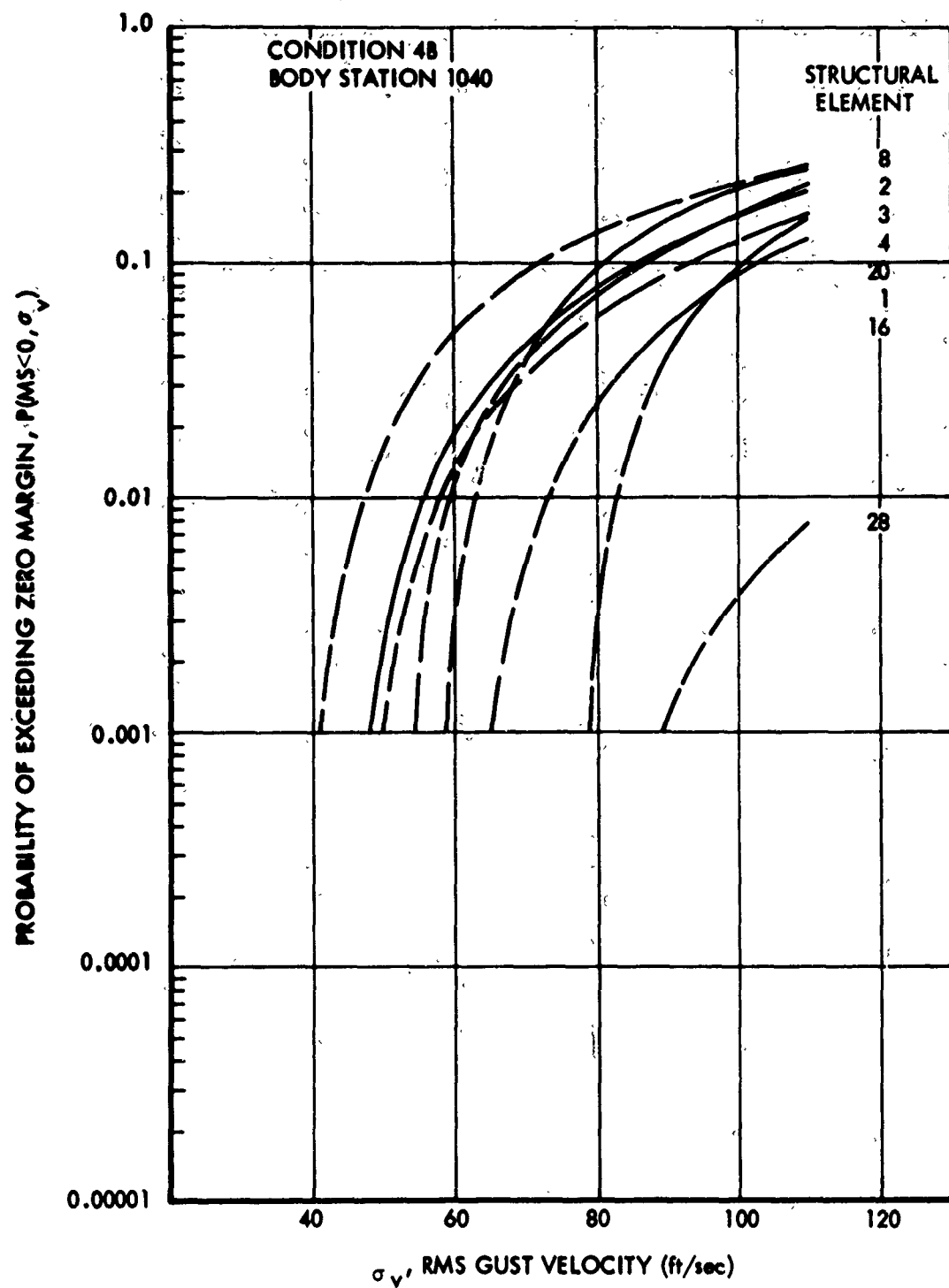


FIGURE 74 (a). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 4B



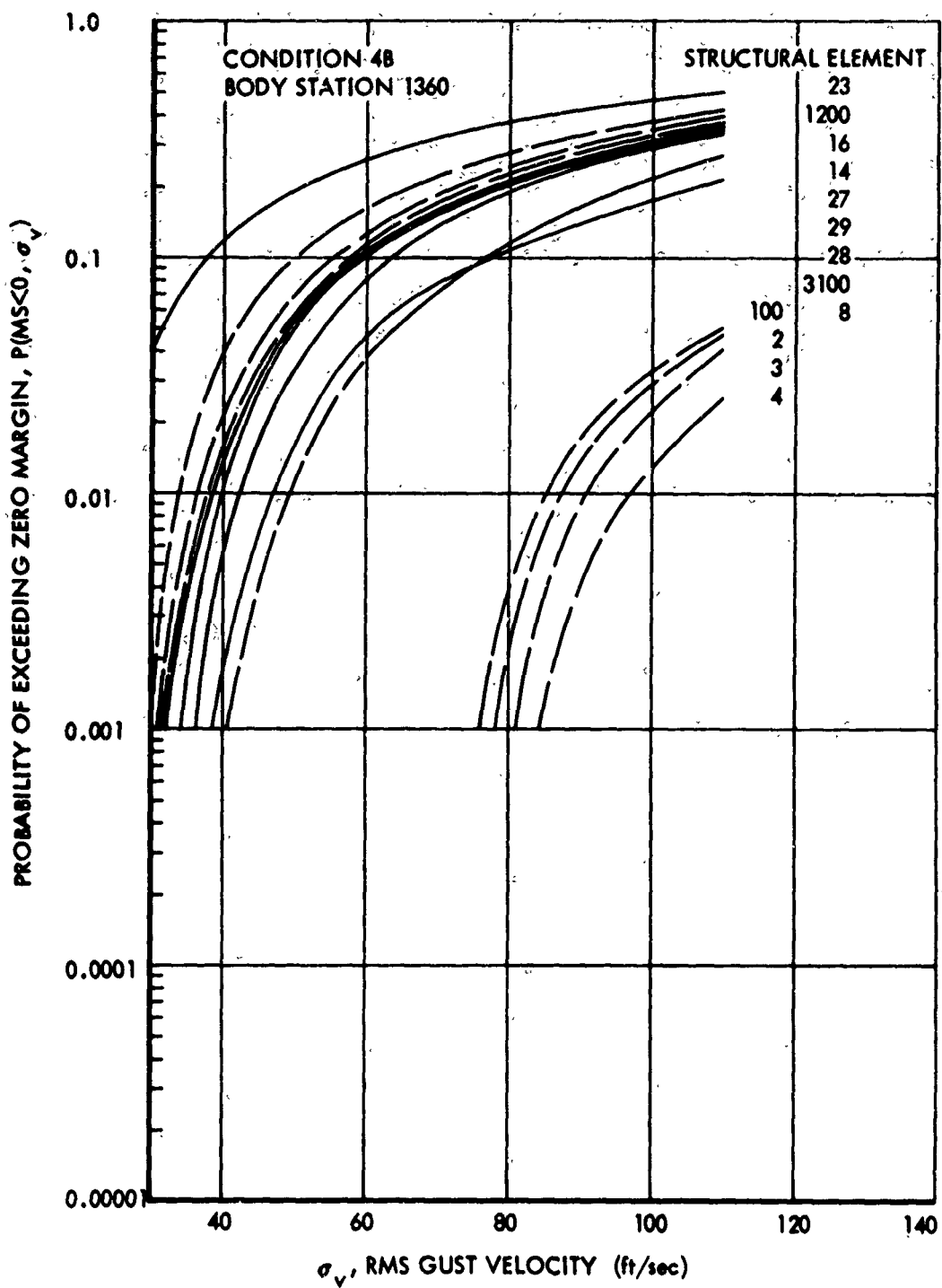


FIGURE 74 (b). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 4B

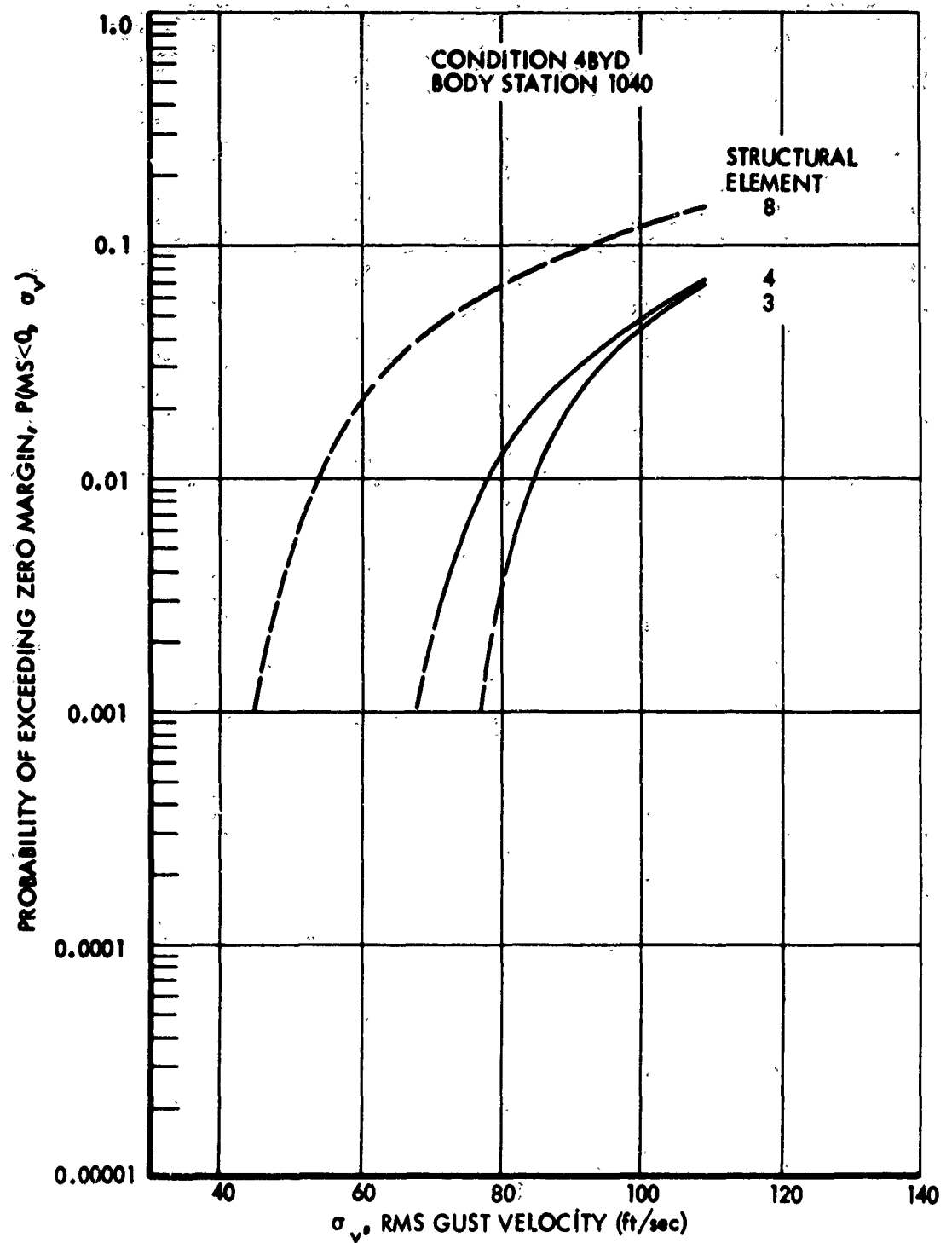


FIGURE 74 (c). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 4BYD

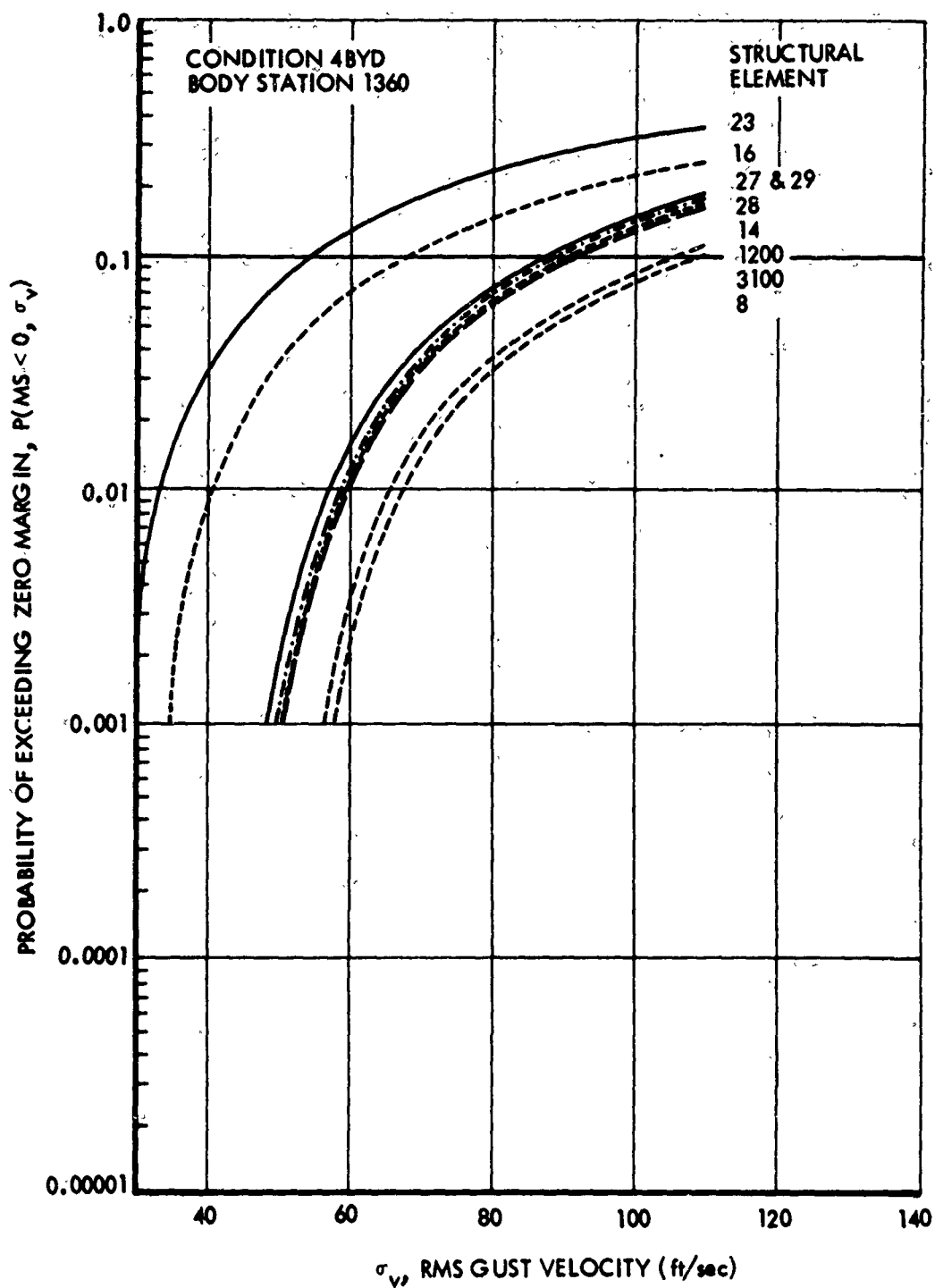


FIGURE 74 (d). PROBABILITY OF EXCEEDING ZERO MARGIN -  
CONDITION 4BYD

# WING $\eta$ STATION .33

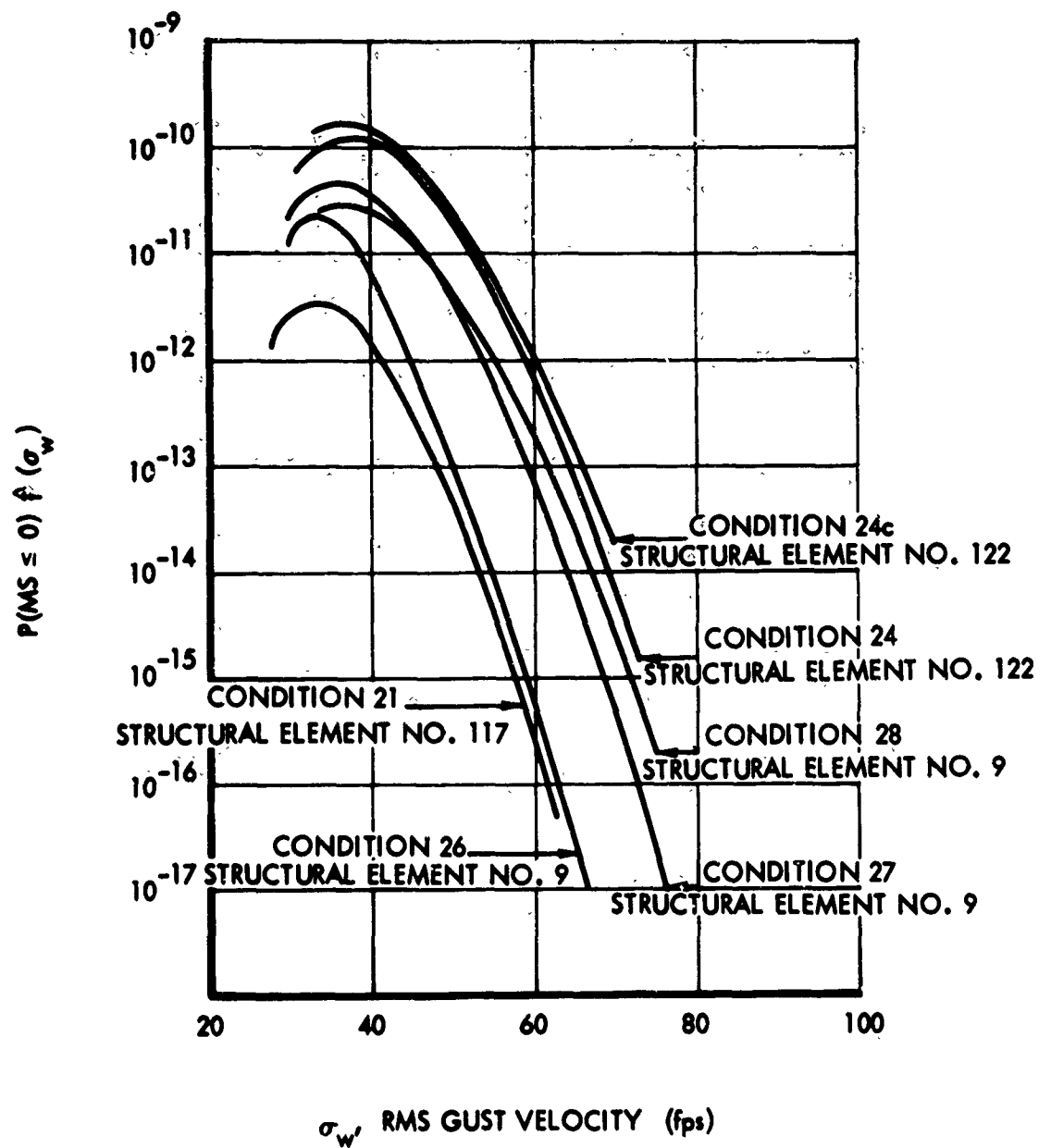


FIGURE 75. OVERALL PROBABILITY OF FAILURE FOR CRITICAL ELEMENTS-WING, VERTICAL ANALYSIS

Values of  $P \times \hat{f}(\sigma_w)$  plotted in this figure are based on one dimensional value of  $P(MS \leq 0)$  vs  $\sigma_w$ . The reason is that the correlation coefficients are very near unity and the predominance of one stress over the other has led to inconsistent numerical integration of the joint probability function. It is believed that the one dimensional value is sufficiently accurate to represent airplane strength.

# BODY VERTICAL ANALYSIS CONDITION 16

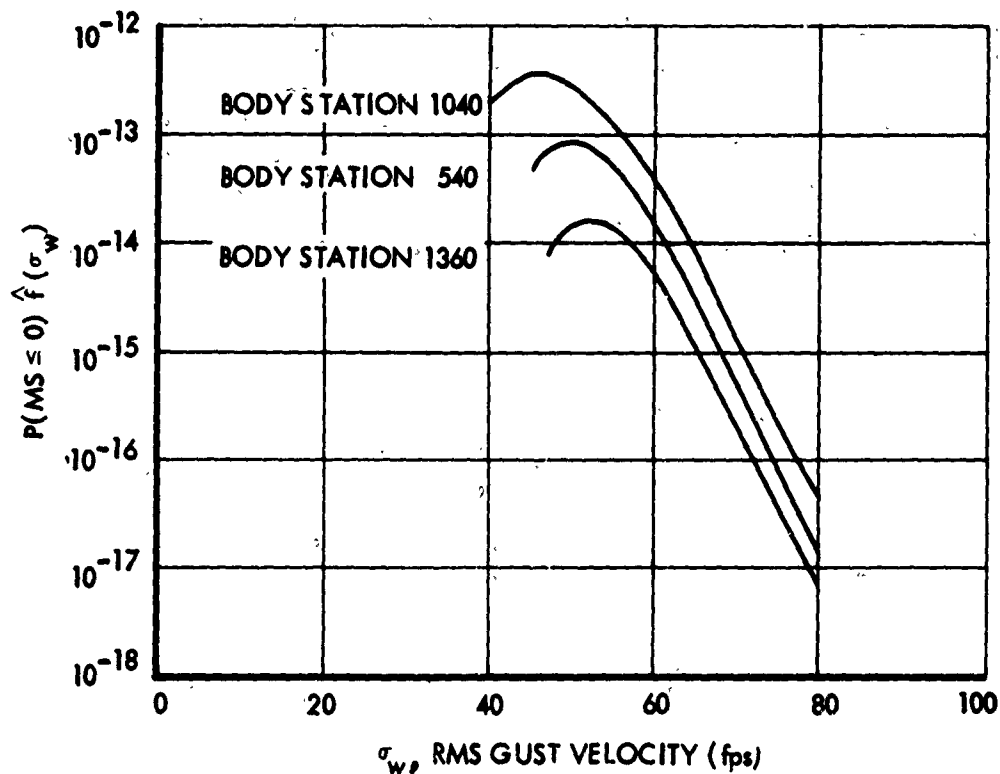


FIGURE 76. OVERALL PROBABILITY OF FAILURE FOR CRITICAL ELEMENTS-BODY, VERTICAL ANALYSIS

# BODY LATERAL ANALYSIS

Values of  $P \times \hat{f}(\sigma_v)$  plotted in this figure are based on one dimensional value of  $P(MS \leq 0)$  vs  $\sigma_v$ . The reason is that the correlation coefficients are very near unity and the predominance of one stress over the other has led to inconsistent numerical integration of the joint probability function. It is believed that the one dimensional value is sufficiently accurate to represent airplane strength.

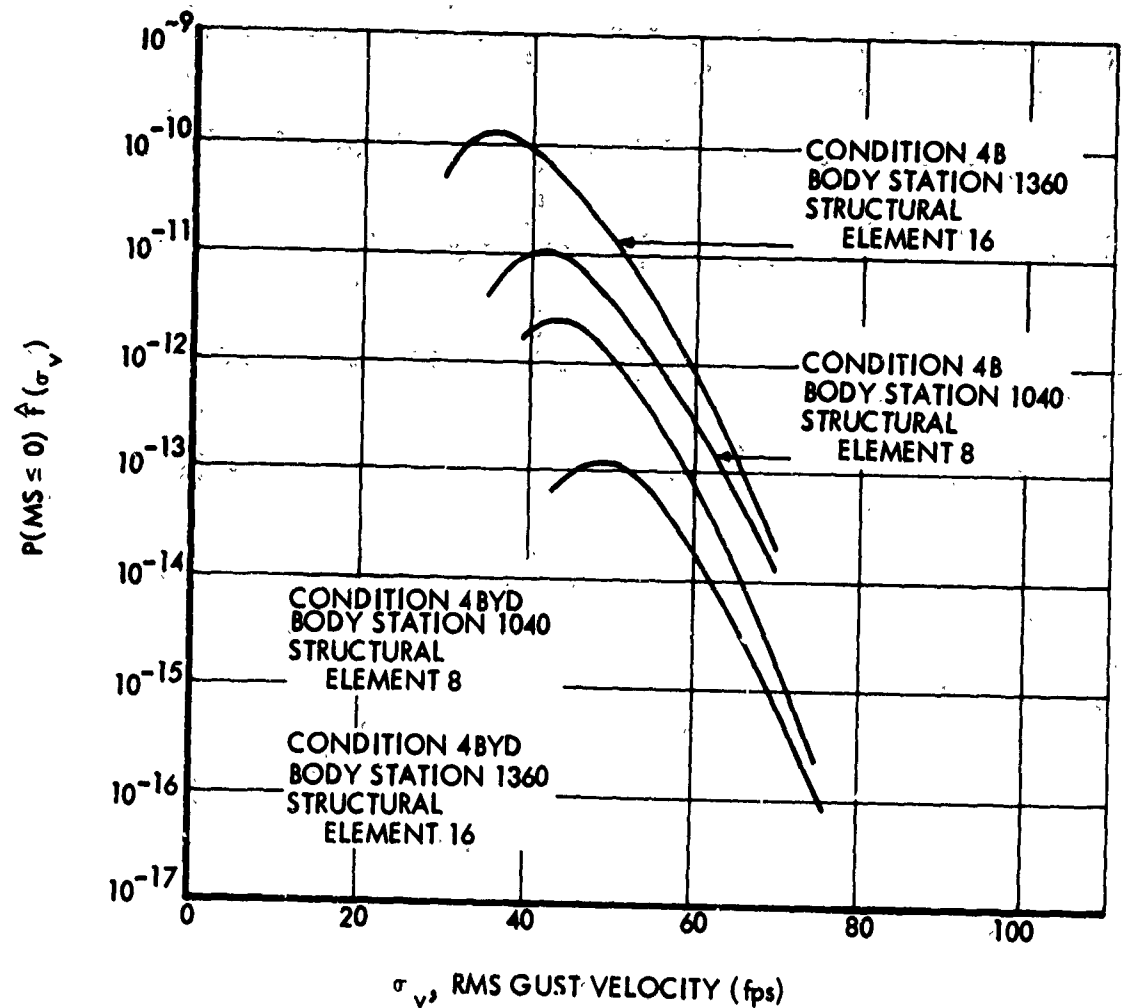


FIGURE 77. OVERALL PROBABILITY OF FAILURE FOR CRITICAL ELEMENTS-BODY, LATERAL ANALYSIS

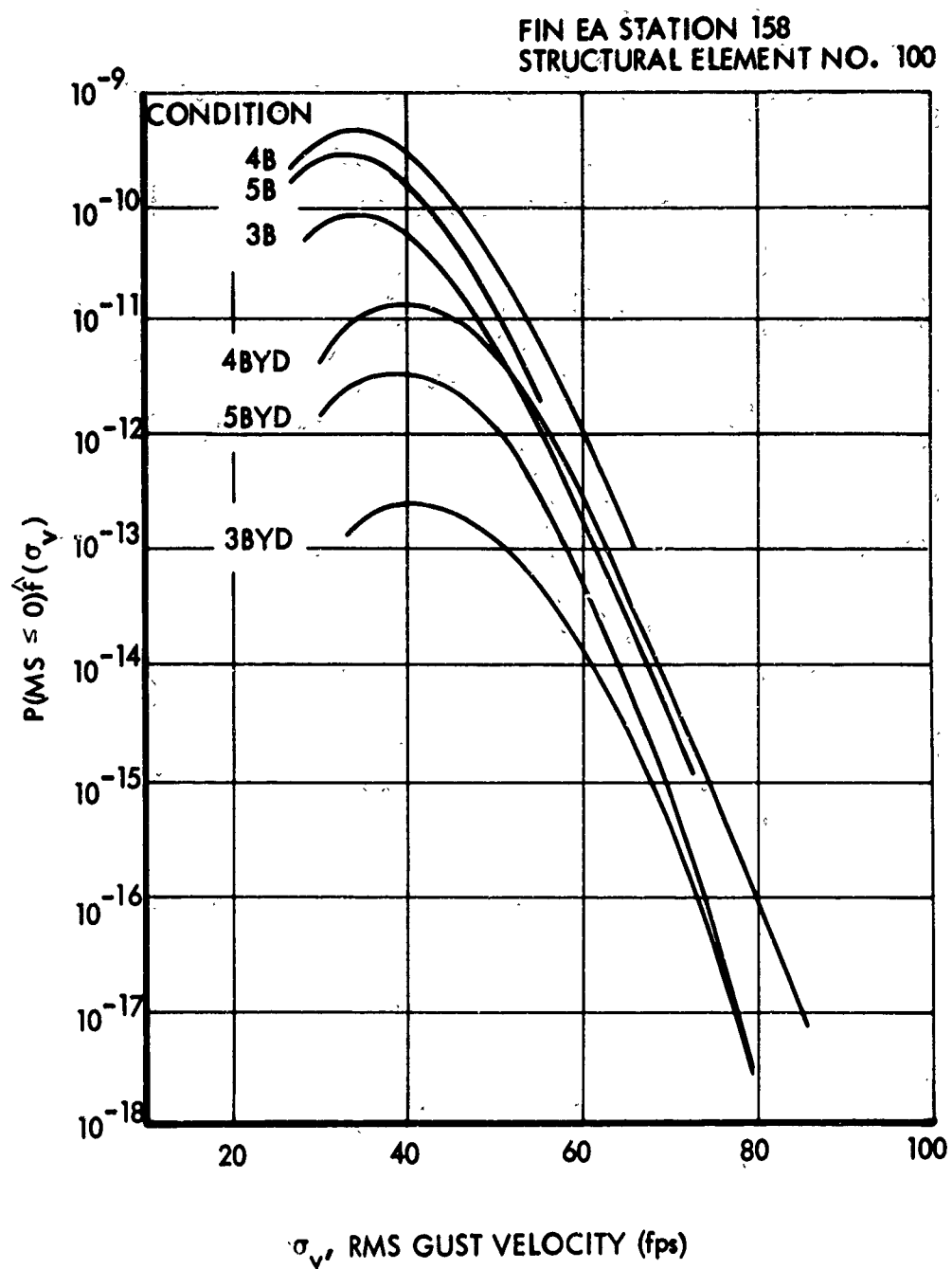


FIGURE 78. OVERALL PROBABILITY OF FAILURE FOR CRITICAL ELEMENTS-VERTICAL TAIL, LATERAL ANALYSIS

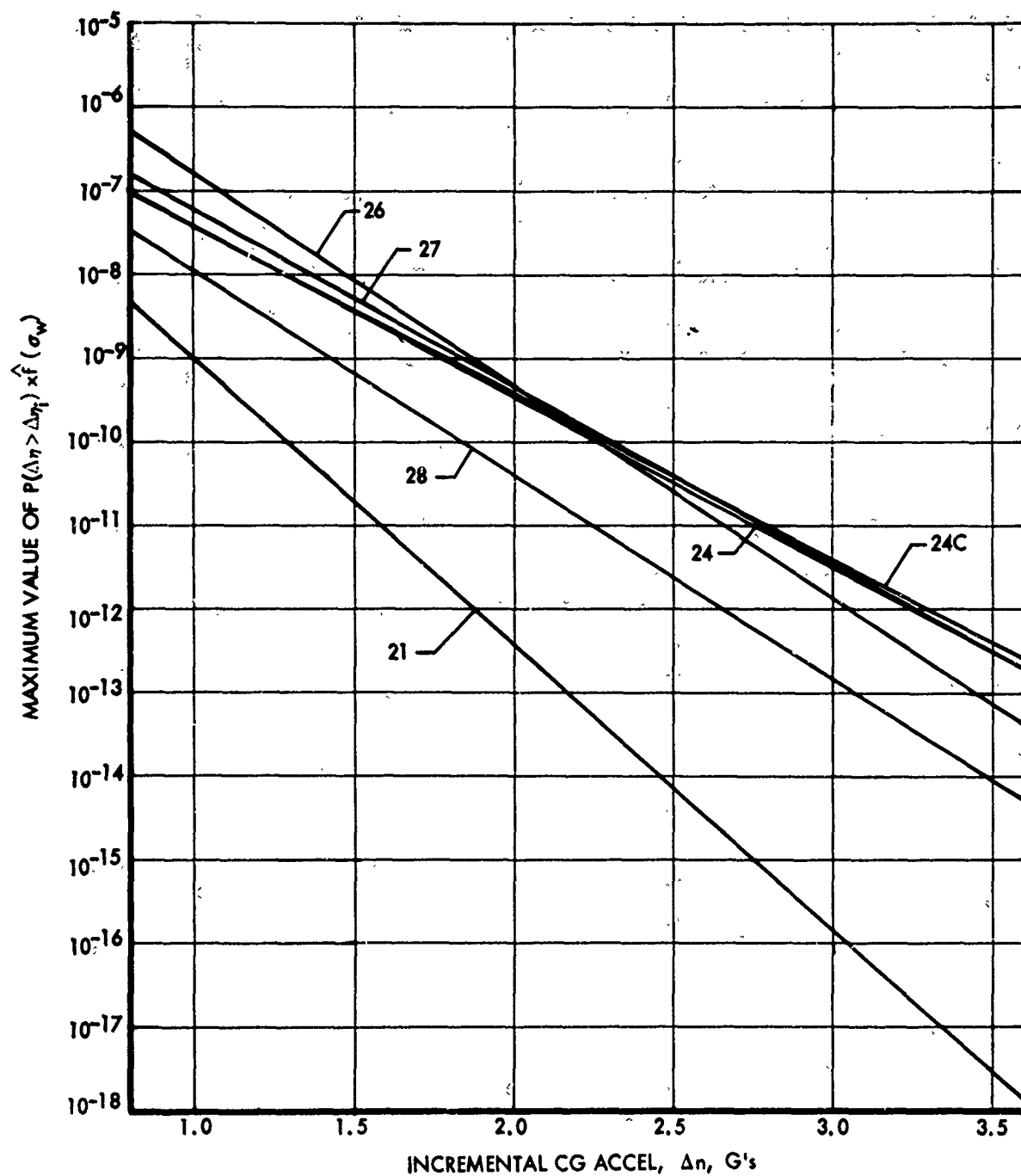


FIGURE 79. VARIATION OF MAXIMUM VALUE OF  $P(\Delta n > \Delta n_i) \times f(\sigma_w)$  WITH INCREMENTAL CG ACCEL,  $\Delta n$



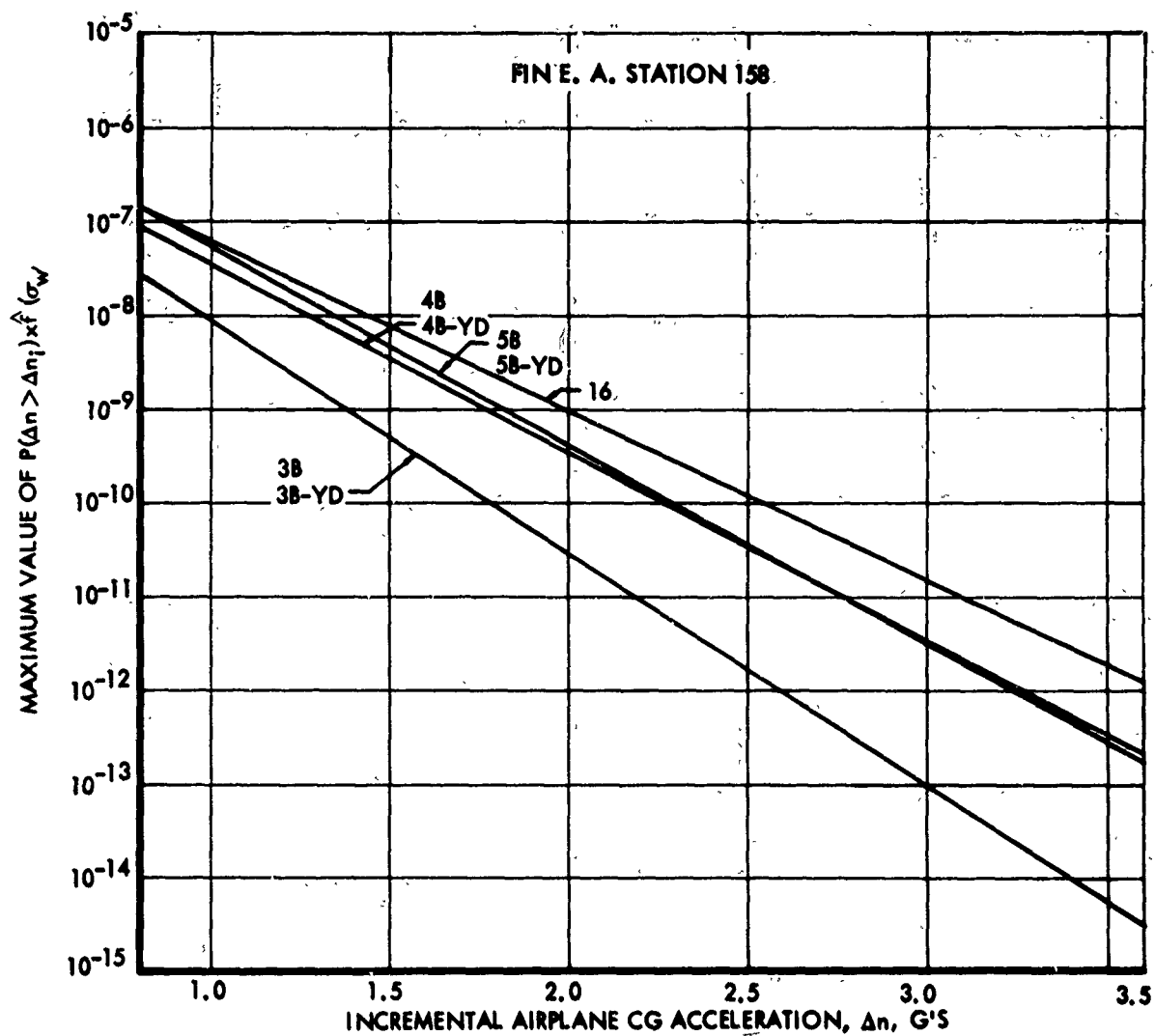


FIGURE 80. VARIATION OF MAXIMUM VALUE OF  $P(\Delta n > \Delta n_i) \times f(\sigma_w)$  WITH INCREMENTAL AIRPLANE CG ACCELERATION,  $\Delta n$

TABLE 12  
SUMMARY OF EXCEEDANCE RATIO VALUES FOR  
DESIGN ENVELOPE CONDITIONS

| Analysis Condition | Station      | $\bar{A} \Delta n$ | $\Delta n_i$ Design | $\sigma_v \eta_d$ | $\sigma_v \eta_d$ | $\frac{N(\sigma_{vnd})}{N(O)}$ | $\frac{N(\sigma_v \eta_d)}{N(O)}$ |
|--------------------|--------------|--------------------|---------------------|-------------------|-------------------|--------------------------------|-----------------------------------|
| 21                 | Wing .33     | .01380             | 1.71                | 124.7             |                   |                                |                                   |
| 24                 | Wing .33     | .01942             | 2.18                | 112.7             |                   |                                |                                   |
| 24C                | Wing .33     | .01977             | 2.19                | 110.8             |                   |                                |                                   |
| 26                 | Wing .33     | .02066             | 2.51                | 121.5             |                   |                                |                                   |
| 27                 | Wing .33     | .02027             | 2.40                | 118.4             |                   |                                |                                   |
| 28                 | Wing .33     | .01670             | 2.06                | 123.3             |                   |                                |                                   |
| 16                 | Body 540     | .02206             | 4.21                | 190.8             |                   |                                |                                   |
|                    | Body 1040    | .02206             | 3.87                | 175.4             |                   |                                |                                   |
|                    | Body 1360    | .02206             | 4.61                | 209.0             |                   |                                |                                   |
| 3B                 | Fin E.A. 158 | .0164              | 1.81                |                   | 110.4             |                                | $6.0(10^{-9})$                    |
| 4B                 | Body 1040    | .0196              | 2.76                |                   | 140.8             |                                | $7.2(10^{-10})$                   |
|                    | Body 1360    | .0196              | 2.20                |                   | 112.2             |                                | $8.0(10^{-9})$                    |
| 5B                 | Fin E.A. 158 | .0196              | 1.93                |                   | 98.5              |                                | $2.3(10^{-8})$                    |
|                    | Fin E.A. 158 | .0202              | 2.04                |                   | 101.0             |                                | $2.3(10^{-8})$                    |
| 3B(YD)             | Fin E.A. 158 | .0164              | 3.35                |                   | 168.9             |                                | $5.0(10^{-11})$                   |
| 4B(YD)             | Body 1040    | .0196              | 3.71                |                   | 189.3             |                                | $1.3(10^{-11})$                   |
|                    | Body 1360    | .0196              | 3.05                |                   | 155.6             |                                | $2.1(10^{-10})$                   |
|                    | Fin E.A. 158 | .0196              | 3.15                |                   | 136.7             |                                | $1.0(10^{-9})$                    |
| 5B(YD)             | Fin E.A. 158 | .0202              | 3.44                |                   | 147.5             |                                | $2.8(10^{-10})$                   |

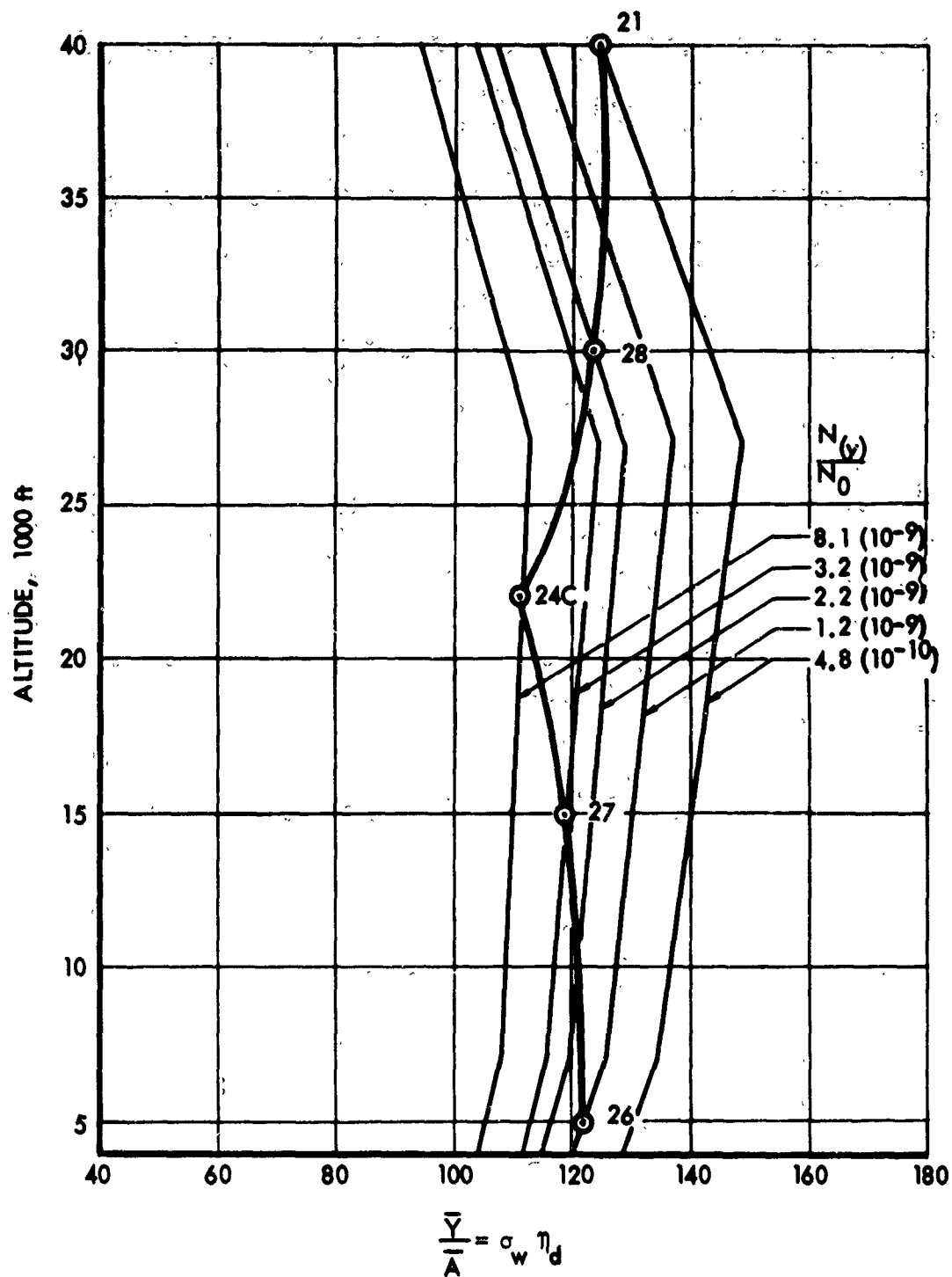


FIGURE 81. VARIATION OF COMBINED STRESS PROBABILITY  $\sigma_w \eta_d$  WITH ALTITUDE

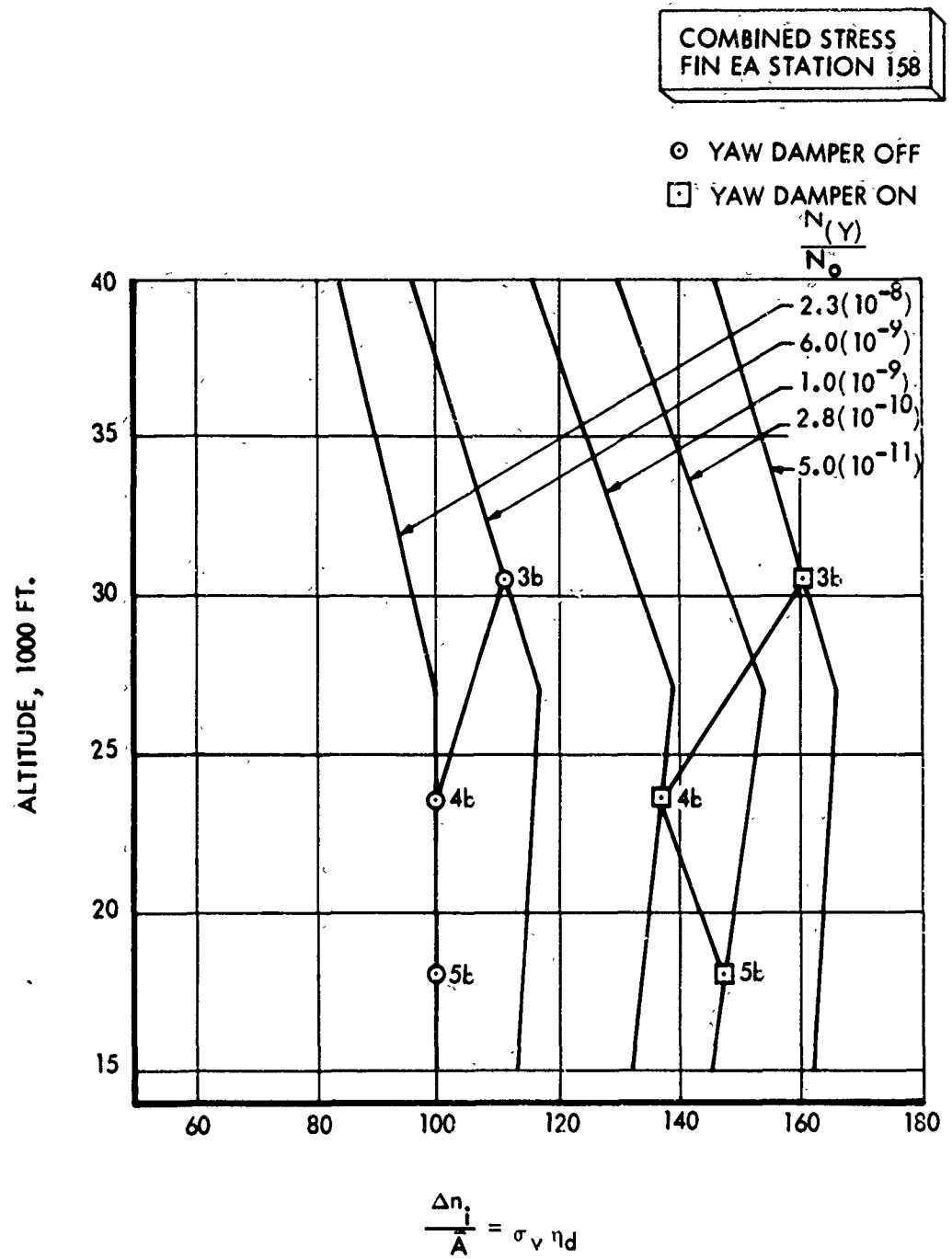


FIGURE 82. VARIATION OF COMBINED STRESS PROBABILITY  $\sigma_v \eta_d$  WITH ALTITUDE

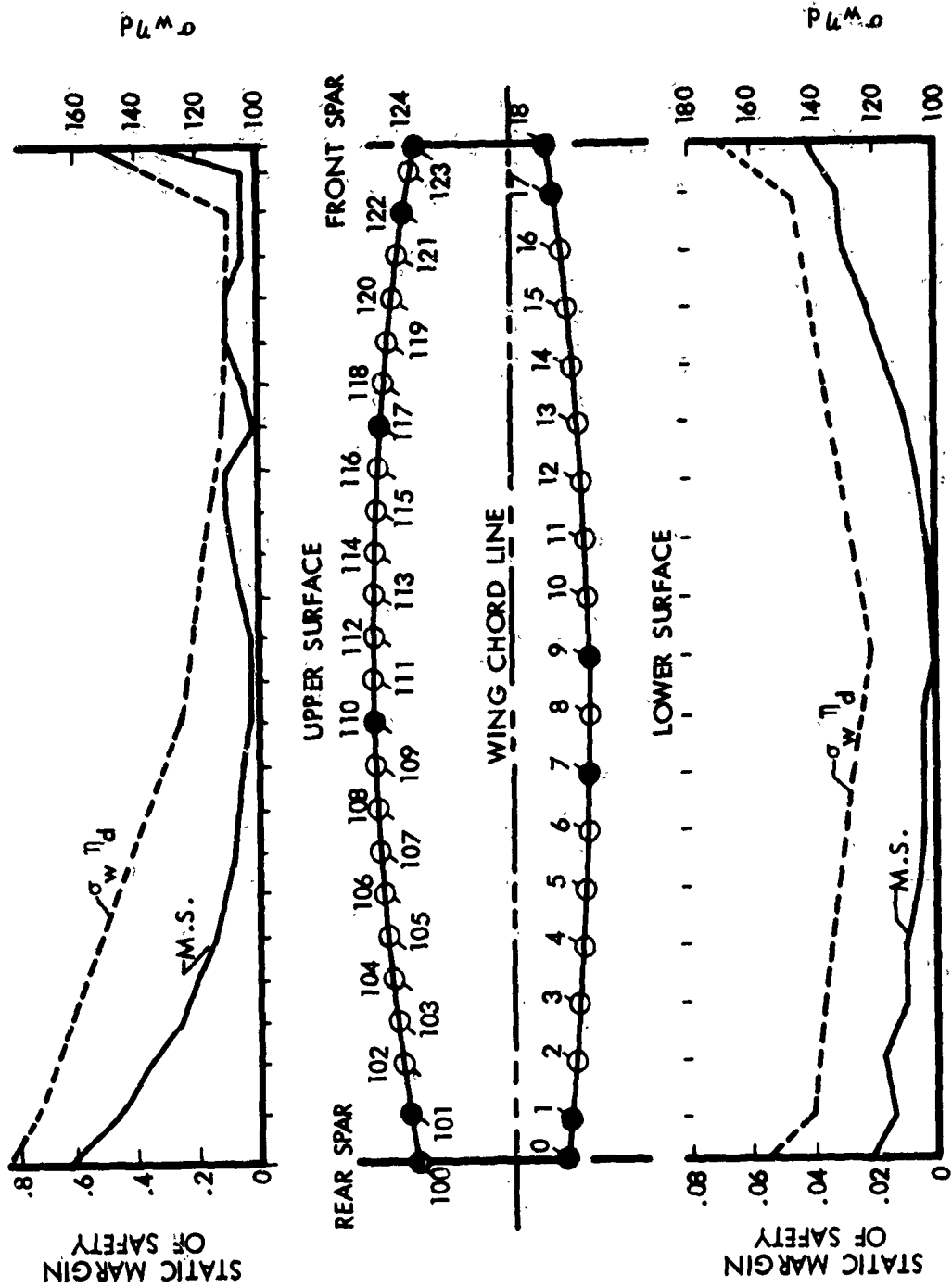


FIGURE 83. COMPARISON OF STATIC MARGIN OF SAFETY WITH  $\sigma_w \eta_d$  - WING ETA STATION.33

difference is that an allowable bending moment for the section would probably be determined by Element 9 while actually under a random type of loading Elements 117 and 122 may be the most critical.

The evaluation of strength capability following the Flight Profile Approach results in number of exceedances per hour of the limit strength envelope. Representative values of the number of exceedances per hour,  $\bar{G}$ , for structural Element 110 are given in Tables 13 through 25 for all the flight profile conditions. The  $\bar{G}$  values for the remaining elements and conditions appears in Volume II, Data Report. The total number of exceedances of the limit design envelope per average flight hour,  $N_p$ , were obtained by multiplying the  $\bar{G}$  values by the appropriate time factors. These values are summarized in Tables 26(a), 26(b) and 26(c).

A summary of the exceedances per hour obtained for the Flight Profile Analysis using the joint probability approach are given in Fig. 84. Also shown in this figure are the design values of  $\sigma_w \eta_d$  and  $\sigma_v \eta_d$  expressed

as exceedance ratios  $\frac{N(\sigma_w \eta_d)}{N(o)}$  and  $\frac{N(\sigma_v \eta_d)}{N(o)}$ .

TABLE 13. EXCEEDANCES PER HOUR - CONDITION 2

|                                  |                |               |                        |                        |  |
|----------------------------------|----------------|---------------|------------------------|------------------------|--|
| 7200 CONDITION 2                 |                |               | VERTICAL GUST ANALYSIS |                        |  |
| WING STA STATION = 0.33          |                |               | STRUCTURAL ELEMENT 110 |                        |  |
| TURBULENCE PARAMETERS            |                |               |                        |                        |  |
| P1 = 0.055000                    |                |               |                        |                        |  |
| P2 = 0.000260                    |                |               |                        |                        |  |
| B1 = 3.370000                    |                |               |                        |                        |  |
| B2 = 10.600000                   |                |               |                        |                        |  |
| IG STRESSES (PSI)                |                |               |                        |                        |  |
| SHEAR                            |                | SKIN          |                        | SEGMENT                |  |
| -1699.0                          |                | -11970.0      |                        | -11440.0               |  |
| V TRUE (FT/SEC) = 624.9          |                |               |                        |                        |  |
| G BAR = 0.3404693E-05 PER HOUR   |                |               |                        |                        |  |
| RMS<br>GUST VELOCITY<br>(FT/SEC) | NC<br>(PER FT) | F (SIGN)      |                        | NC F (SIGN)<br>X 1000V |  |
| 10.                              | 0.             | 0.1719984E-03 |                        | 0.                     |  |
| 15.                              | 0.1153180E-19  | 0.7840254E-05 |                        | 0.1016999E-10          |  |
| 20.                              | 0.5396531E-12  | 0.3300692E-05 |                        | 0.2003609E-11          |  |
| 22.                              | 0.2773744E-10  | 0.2271063E-05 |                        | 0.7085801E-10          |  |
| 24.                              | 0.5548958E-09  | 0.1508094E-05 |                        | 0.9413113E-09          |  |
| 26.                              | 0.9710621E-08  | 0.9664248E-06 |                        | 0.6207902E-08          |  |
| 28.                              | 0.3630455E-07  | 0.5976501E-06 |                        | 0.2440628E-07          |  |
| 30.                              | 0.1614155E-06  | 0.3566687E-06 |                        | 0.6475955E-07          |  |
| 32.                              | 0.5473124E-06  | 0.2054103E-06 |                        | 0.1264594E-06          |  |
| 34.                              | 0.1505583E-05  | 0.1141613E-06 |                        | 0.1933379E-06          |  |
| 36.                              | 0.3515394E-05  | 0.6122861E-07 |                        | 0.2421150E-06          |  |
| 38.                              | 0.7205064E-05  | 0.3169051E-07 |                        | 0.2568387E-06          |  |
| 40.                              | 0.1329642E-04  | 0.1582862E-07 |                        | 0.2367398E-06          |  |
| 45.                              | 0.4372390E-04  | 0.2388290E-08 |                        | 0.1174625E-06          |  |
| 50.                              | 0.1024688E-03  | 0.2884700E-09 |                        | 0.3324957E-07          |  |
| 55.                              | 0.1924672E-03  | 0.2789229E-10 |                        | 0.6038573E-08          |  |
| 60.                              | 0.3109628E-03  | 0.2158926E-11 |                        | 0.7551610E-09          |  |
| 65.                              | 0.4519064E-03  | 0.1337707E-12 |                        | 0.6797906E-10          |  |
| 70.                              | 0.6083729E-03  | 0.6635201E-14 |                        | 0.4540643E-11          |  |
| 75.                              | 0.7741492E-03  | 0.2634615E-15 |                        | 0.2294271E-12          |  |
| 80.                              | 0.9444643E-03  | 0.8374370E-17 |                        | 0.8896702E-14          |  |

TABLE 14. EXCEEDANCES PER HOUR - CONDITION 4

| 7200 CONDITION 4 VERTICAL GUST ANALYSIS |                |                        |                       |
|-----------------------------------------|----------------|------------------------|-----------------------|
| WING STA STATION = 0.33                 |                | STRUCTURAL ELEMENT 110 |                       |
| TURBULENCE PARAMETERS                   |                |                        |                       |
| P1 = 0.055000                           |                |                        |                       |
| P2 = 0.000260                           |                |                        |                       |
| B1 = 3.370000                           |                |                        |                       |
| B2 = 10.600000                          |                |                        |                       |
| 16 STRESSES (PSI)                       |                |                        |                       |
| SHEAR                                   |                | SKIN                   | SEGMENT               |
| -1747.0                                 |                | -10650.0               | -10180.0              |
| V TRUE (FT/SEC) = 624.9                 |                |                        |                       |
| G BAR = 0.1394977E-05 PER HOUR          |                |                        |                       |
| RMS<br>GUST VELOCITY<br>(FT/SEC)        | NC<br>(PER FT) | F (SIGN)               | NC F(SIGN)<br>X 1000V |
| 10.                                     | 0.             | 0.1719984E-03          | 0.                    |
| 15.                                     | 0.2927206E-22  | 0.7840254E-05          | 0.2581528E-21         |
| 20.                                     | 0.1879234E-13  | 0.3300692E-05          | 0.6977170E-13         |
| 22.                                     | 0.1734891E-11  | 0.2271063E-05          | 0.4431951E-11         |
| 24.                                     | 0.5419869E-10  | 0.1508094E-05          | 0.9194129E-10         |
| 26.                                     | 0.7891885E-09  | 0.9664248E-06          | 0.8579111E-09         |
| 28.                                     | 0.6608456E-08  | 0.5976501E-06          | 0.4442633E-08         |
| 30.                                     | 0.3669767E-07  | 0.3566687E-06          | 0.1472302E-07         |
| 32.                                     | 0.1492705E-06  | 0.2054103E-06          | 0.3448972E-07         |
| 34.                                     | 0.4774964E-06  | 0.1141613E-06          | 0.6131720E-07         |
| 36.                                     | 0.1265207E-05  | 0.6122861E-07          | 0.8713839E-07         |
| 38.                                     | 0.2886112E-05  | 0.3169051E-07          | 0.1028811E-06         |
| 40.                                     | 0.5835854E-05  | 0.1582862E-07          | 0.1039061E-06         |
| 45.                                     | 0.2291970E-04  | 0.2388290E-08          | 0.6157288E-07         |
| 50.                                     | 0.6098791E-04  | 0.2884700E-09          | 0.1978964E-07         |
| 55.                                     | 0.1258393E-03  | 0.2789279E-10          | 0.3948154E-08         |
| 60.                                     | 0.2183767E-03  | 0.2158926E-11          | 0.5303193E-09         |
| 65.                                     | 0.3355208E-03  | 0.1337707E-12          | 0.5048635E-10         |
| 70.                                     | 0.4721346E-03  | 0.6635201E-14          | 0.3523817E-11         |
| 75.                                     | 0.6227358E-03  | 0.2634615E-15          | 0.1845502E-12         |
| 80.                                     | 0.7825570E-03  | 0.8374330E-17          | 0.7371561E-14         |



TABLE 15. EXCEEDANCES PER HOUR - CONDITION 5

|                                         |                |                        |                       |
|-----------------------------------------|----------------|------------------------|-----------------------|
| 7200 CONDITION 5 VERTICAL GUST ANALYSIS |                |                        |                       |
| WING STA STATION = 0.33                 |                | STRUCTURAL ELEMENT 110 |                       |
| TURBULENCE PARAMETERS                   |                |                        |                       |
| P1 = 0.055000                           |                |                        |                       |
| P2 = 0.000760                           |                |                        |                       |
| B1 = 3.370000                           |                |                        |                       |
| B2 = 10.600000                          |                |                        |                       |
| 16 STRESSES (PSI)                       |                |                        |                       |
| SHEAR                                   |                | SKIN                   | SEGMENT               |
| -1701.0                                 |                | -11820.0               | -11290.0              |
| V TRUE (FT/SEC) = 624.9                 |                |                        |                       |
| G BAR = 0.3014469E-05 PER HOUR          |                |                        |                       |
| RMS<br>GUST VELOCITY<br>(FT/SEC)        | NC<br>(PER FT) | F (SIGW)               | NC F(SIGW)<br>X 1000V |
| 10.                                     | 0.             | 0.1719984E-03          | 0.                    |
| 15.                                     | 0.1178477E-19  | 0.7840254E-05          | 0.1039309E-18         |
| 20.                                     | 0.5139476E-12  | 0.3300692E-05          | 0.1908171E-11         |
| 22.                                     | 0.2595945E-10  | 0.2271063E-05          | 0.6631596E-10         |
| 24.                                     | 0.5123709E-09  | 0.1508094E-05          | 0.8691731E-09         |
| 26.                                     | 0.5217883E-08  | 0.9664248E-06          | 0.5672256E-08         |
| 28.                                     | 0.3289814E-07  | 0.5976501E-06          | 0.2211626E-07         |
| 30.                                     | 0.1453013E-06  | 0.3566687E-06          | 0.5829454E-07         |
| 32.                                     | 0.4900137E-06  | 0.2054103E-06          | 0.1132202E-06         |
| 34.                                     | 0.1341939E-05  | 0.1141613E-06          | 0.1723237E-06         |
| 36.                                     | 0.3121549E-05  | 0.6122861E-07          | 0.2149898E-06         |
| 38.                                     | 0.6377445E-05  | 0.3169051E-07          | 0.2273366E-06         |
| 40.                                     | 0.1173683E-04  | 0.1582862E-07          | 0.2089717E-06         |
| 45.                                     | 0.3838632E-04  | 0.2388290E-08          | 0.1031233E-06         |
| 50.                                     | 0.8959862E-04  | 0.2884700E-09          | 0.2907338E-07         |
| 55.                                     | 0.1677697E-03  | 0.2789229E-10          | 0.5263701E-08         |
| 60.                                     | 0.2703872E-03  | 0.2158976E-11          | 0.6566247E-09         |
| 65.                                     | 0.3921508E-03  | 0.1337707E-12          | 0.5900755E-10         |
| 70.                                     | 0.5270784E-03  | 0.6635201E-14          | 0.3933895E-11         |
| 75.                                     | 0.6698677E-03  | 0.2634615E-15          | 0.1985179E-12         |
| 80.                                     | 0.8165000E-03  | 0.8374330E-17          | 0.7691299E-14         |

TABLE 16. EXCEEDANCES PER HOUR - CONDITION 6

|                                  |                |                        |                       |
|----------------------------------|----------------|------------------------|-----------------------|
| 7700 CONDITION 6                 |                | VERTICAL GUST ANALYSIS |                       |
| WING ETA STATION = 0.33          |                | STRUCTURAL ELEMENT 110 |                       |
| TURBULENCE PARAMETERS            |                |                        |                       |
| P1 = 0.055000                    |                |                        |                       |
| P2 = 0.000760                    |                |                        |                       |
| B1 = 3.370000                    |                |                        |                       |
| B2 = 10.600000                   |                |                        |                       |
| IG STRESSES (PSI)                |                |                        |                       |
| SHEAR                            | SKIN           | SEGMENT                |                       |
| -1133.0                          | -11970.0       | -11440.0               |                       |
| V TRUF (FT/SEC) = 624.9          |                |                        |                       |
| G MAX = 0.2208273E-05 PER HOUR   |                |                        |                       |
| RMS<br>GUST VELOCITY<br>(FT/SEC) | NC<br>(PER FT) | F (SIGN)               | NC F(SIGN)<br>X 1000V |
| 10.                              | 0.             | 0.1714984E-03          | 0.                    |
| 15.                              | 0.1209854E-20  | 0.7840254E-05          | 0.1066981E-19         |
| 20.                              | 0.1436026E-12  | 0.3300497E-05          | 0.5331677E-17         |
| 22.                              | 0.9116727E-11  | 0.2271063E-05          | 0.2328958E-10         |
| 24.                              | 0.2143667E-09  | 0.1508094E-05          | 0.3636463E-09         |
| 26.                              | 0.2503280E-08  | 0.9664248E-06          | 0.2721266E-08         |
| 28.                              | 0.1760009E-07  | 0.5976501E-06          | 0.1183191E-07         |
| 30.                              | 0.8687839E-07  | 0.3566687E-06          | 0.3406104E-07         |
| 32.                              | 0.3077842E-06  | 0.2054103E-06          | 0.7111514E-07         |
| 34.                              | 0.8950631E-06  | 0.1141613E-06          | 0.1149396E-06         |
| 36.                              | 0.2189714E-05  | 0.6122861E-07          | 0.1508117E-06         |
| 38.                              | 0.4669008E-05  | 0.3169051E-07          | 0.1664360E-06         |
| 40.                              | 0.8912478E-05  | 0.1582862E-07          | 0.1586847E-06         |
| 45.                              | 0.3127818E-04  | 0.2384290E-08          | 0.8408185E-07         |
| 50.                              | 0.7688043E-04  | 0.2984700E-09          | 0.2494652E-07         |
| 55.                              | 0.1495137E-03  | 0.2782229E-10          | 0.4690927E-08         |
| 60.                              | 0.2680278E-03  | 0.2154926E-11          | 0.6023258E-09         |
| 65.                              | 0.3679045E-03  | 0.1337707E-12          | 0.5535917E-10         |
| 70.                              | 0.5033467E-03  | 0.6635301E-14          | 0.3756771E-11         |
| 75.                              | 0.6449000E-03  | 0.3636151E-15          | 0.1922744E-12         |
| 80.                              | 0.7927630E-03  | 0.9376330E-17          | 0.7533639E-14         |

TABLE 17. EXCEEDANCES PER HOUR - CONDITION 7

|                                         |                |                        |                        |
|-----------------------------------------|----------------|------------------------|------------------------|
| 7200 CONDITION 7 VERTICAL GUST ANALYSIS |                |                        |                        |
| WING ETA STATION = 0.33                 |                | STRUCTURAL ELEMENT 110 |                        |
| TURBULENCE PARAMETERS                   |                |                        |                        |
| P1 = 0.016500                           |                |                        |                        |
| P2 = 0.000090                           |                |                        |                        |
| B1 = 3.050000                           |                |                        |                        |
| B2 = 11.400000                          |                |                        |                        |
| IG STRESSES (PSI)                       |                |                        |                        |
| SHEAR                                   | SKIN           | SEGMENT                |                        |
| -2274.0                                 | -11740.0       | -11220.0               |                        |
| V TRUE (FT/SEC) = 810.7                 |                |                        |                        |
| G BAR = 0.2418557E-05 PER HOUR          |                |                        |                        |
| RMS<br>GUST VELOCITY<br>(FT/SEC)        | NC<br>(PER FT) | F (SIGW)               | NC F (SIGW)<br>X 1000V |
| 10.                                     | 0.             | 0.2427838E-04          | 0.                     |
| 15.                                     | 0.1119441E-20  | 0.2674668E-05          | 0.4369217E-20          |
| 20.                                     | 0.1367588E-12  | 0.1351946E-05          | 0.2697834E-12          |
| 22.                                     | 0.8729709E-11  | 0.9785274E-06          | 0.1246538E-10          |
| 24.                                     | 0.2060932E-09  | 0.6868347E-06          | 0.2065612E-09          |
| 26.                                     | 0.2414129E-08  | 0.4674816E-06          | 0.1646864E-08          |
| 28.                                     | 0.1701507E-07  | 0.3085388E-06          | 0.7660814E-08          |
| 30.                                     | 0.8223965E-07  | 0.1974640E-06          | 0.2369746E-07          |
| 32.                                     | 0.2986331E-06  | 0.1225460E-06          | 0.5340351E-07          |
| 34.                                     | 0.8696330E-06  | 0.7374682E-07          | 0.9358624E-07          |
| 36.                                     | 0.2129936E-05  | 0.4303487E-07          | 0.1337580E-06          |
| 38.                                     | 0.4545960E-05  | 0.2435177E-07          | 0.1615433E-06          |
| 40.                                     | 0.8684816E-05  | 0.1336207E-07          | 0.1693429E-06          |
| 45.                                     | 0.3054843E-04  | 0.2604658E-08          | 0.1161107E-06          |
| 50.                                     | 0.7512609E-04  | 0.4188745E-09          | 0.4592059E-07          |
| 55.                                     | 0.1462309E-03  | 0.5557420E-10          | 0.1185892E-07          |
| 60.                                     | 0.2427509E-03  | 0.6093012E-11          | 0.2154826E-08          |
| 65.                                     | 0.3602802E-03  | 0.5493134E-12          | 0.2887974E-09          |
| 70.                                     | 0.4931376E-03  | 0.4092398E-13          | 0.2944931E-10          |
| 75.                                     | 0.6358298E-03  | 0.2515311E-14          | 0.2333809E-11          |
| 80.                                     | 0.7838896E-03  | 0.1275445E-15          | 0.1458980E-12          |

TABLE 18. EXCEEDANCES PER HOUR - CONDITION 7 (31,000 FT.)

720R CONDITION 7

VERTICAL GUST ANALYSIS

WING STA STATION = 0.11

STRUCTURAL ELEMENT 110

ALTITUDE 31,000 FT.

TURBULENCE PARAMETERS

P1 = 0.015000

P2 = 0.000090

R1 = 3.000000

R2 = 11.250000

IG STRESSES (PSI)

SHEAR

SKIN

SEGMENT

-2274.0

-11740.0

-11220.0

V TRUE (FT/SEC) = 910.7

G RAP = 0.2056367E-05 PER HOUR

| RMS<br>GUST VELOCITY<br>(FT/SEC) | NC<br>(PER FT) | F (SIGM)      | NC F (SIGM)<br>X 1000V |
|----------------------------------|----------------|---------------|------------------------|
| 10.                              | 0.             | 0.1972267E-04 | 0.                     |
| 15.                              | 0.1117441E-20  | 0.2637028E-05 | 0.4310997E-20          |
| 20.                              | 0.1367588E-12  | 0.1314431E-05 | 0.2623165E-12          |
| 22.                              | 0.8729707E-11  | 0.7432267E-06 | 0.1201568E-10          |
| 24.                              | 0.2060937E-09  | 0.6557961E-06 | 0.1972265E-09          |
| 26.                              | 0.2414129E-08  | 0.4417695E-06 | 0.1556284E-08          |
| 28.                              | 0.1701502E-07  | 0.2883346E-06 | 0.7159157E-08          |
| 30.                              | 0.8223945E-07  | 0.1823358E-06 | 0.2188194E-07          |
| 32.                              | 0.2996331E-06  | 0.1117175E-06 | 0.4868463E-07          |
| 34.                              | 0.8676330E-06  | 0.6632002E-07 | 0.8416147E-07          |
| 36.                              | 0.2129936E-05  | 0.3814541E-07 | 0.1185607E-06          |
| 38.                              | 0.4545960E-05  | 0.2125757E-07 | 0.1410173E-06          |
| 40.                              | 0.8684816E-05  | 0.1147783E-07 | 0.1454632E-06          |
| 45.                              | 0.3054843E-04  | 0.2141284E-08 | 0.9545435E-07          |
| 50.                              | 0.7512609E-04  | 0.3278701E-09 | 0.3594391E-07          |
| 55.                              | 0.1462309E-03  | 0.4120434E-10 | 0.8792547E-08          |
| 60.                              | 0.2427507E-03  | 0.4250083E-11 | 0.1505535E-08          |
| 65.                              | 0.3602802E-03  | 0.3598035E-12 | 0.1891640E-09          |
| 70.                              | 0.4931336E-03  | 0.2500039E-13 | 0.1799053E-10          |
| 75.                              | 0.6358298E-03  | 0.1425744E-14 | 0.1322864E-11          |
| 80.                              | 0.7838896E-03  | 0.4673441E-16 | 0.7633740E-13          |

TABLE 19. EXCEEDANCES PER HOUR - CONDITION 8

|                                          |                |                        |                        |
|------------------------------------------|----------------|------------------------|------------------------|
| 7200 CONDITION 8: VERTICAL GUST ANALYSIS |                |                        |                        |
| WING FEA STATION = 0.33                  |                | STRUCTURAL ELEMENT 110 |                        |
| TURBULENCE PARAMETERS                    |                |                        |                        |
| R1 = 0.010500                            |                |                        |                        |
| R2 = 0.000000                            |                |                        |                        |
| R1 = 2.250000                            |                |                        |                        |
| R2 = 0.450000                            |                |                        |                        |
| IG STRESSIS (PSI)                        |                |                        |                        |
| SHEAR                                    | SKIN           | SEGMENT                |                        |
| -2242.0                                  | -12360.0       | -11410.0               |                        |
| V TRUE (FT/SEC) = 402.1                  |                |                        |                        |
| G BAR = 0.2047245E-06 PER HOUR           |                |                        |                        |
| RMS<br>GUST VELOCITY<br>(FT/SEC.)        | NC<br>(PER FT) | F (SIGN)               | NC F (SIGN)<br>X 1000V |
| 10.                                      | 0.             | 0.1343433E-04          | 0.                     |
| 15.                                      | 0.4392325E-22  | 0.2223407E-05          | 0.1454677E-21          |
| 20.                                      | 0.2190014E-13  | 0.9279008E-06          | 0.2934625E-13          |
| 22.                                      | 0.1912570E-11  | 0.6014662E-06          | 0.1662273E-11          |
| 24.                                      | 0.5731040E-10  | 0.3744233E-06          | 0.3100352E-10          |
| 26.                                      | 0.4082305E-09  | 0.2237609E-06          | 0.2611661E-09          |
| 28.                                      | 0.6600714E-08  | 0.1282526E-06          | 0.1222481E-08          |
| 30.                                      | 0.3593097E-07  | 0.7054160E-07          | 0.3660153E-08          |
| 32.                                      | 0.1439106E-06  | 0.3723226E-07          | 0.7732052E-08          |
| 34.                                      | 0.4539670E-06  | 0.1885769E-07          | 0.1236223E-07          |
| 36.                                      | 0.1189647E-05  | 0.9165330E-08          | 0.1574548E-07          |
| 38.                                      | 0.2688633E-05  | 0.4274745E-08          | 0.1659696E-07          |
| 40.                                      | 0.5393733E-05  | 0.1913228E-08          | 0.1490185E-07          |
| 45.                                      | 0.2086166E-06  | 0.2140745E-09          | 0.6449156E-08          |
| 50.                                      | 0.5490491E-06  | 0.1851253E-10          | 0.1667887E-08          |
| 55.                                      | 0.1123830E-03  | 0.1237248E-11          | 0.2007401E-09          |
| 60.                                      | 0.1934156E-03  | 0.6390609E-13          | 0.1788611E-10          |
| 65.                                      | 0.2962997E-03  | 0.2551068E-14          | 0.1091494E-11          |
| 70.                                      | 0.4150467E-03  | 0.7870332E-16          | 0.4717584E-13          |
| 75.                                      | 0.5451336E-03  | 0.1976571E-17          | 0.1477246E-14          |
| 80.                                      | 0.6819978E-03  | 0.3454034E-19          | 0.3605118E-16          |

TABLE 20. EXCEEDANCES PER HOUR - CONDITION 8 (33,000 FT.)

| CONDITION 8                      |                | VERTICAL GUST ANALYSIS |                        |
|----------------------------------|----------------|------------------------|------------------------|
| WING ETA STATION = 0.33          |                | STRUCTURAL ELEMENT 110 |                        |
| ALTITUDE 33,000 FT.              |                |                        |                        |
| TURBULENCE PARAMETERS            |                |                        |                        |
| P1 = 0.012500                    |                |                        |                        |
| P2 = 0.000070                    |                |                        |                        |
| B1 = 2.970000                    |                |                        |                        |
| B2 = 10.400000                   |                |                        |                        |
| IG STRESSES (PSI)                |                |                        |                        |
| SHEAR                            |                | SKIN                   | SEGMENT                |
| -2247.0                          |                | -12360.0               | -11810.0               |
| V TRUE (FT/SEC) = 802.3          |                |                        |                        |
| G BAR = 0.4429345E-06 PER HOUR   |                |                        |                        |
| RMS<br>GUST VELOCITY<br>(FT/SEC) | NC<br>(PER FT) | F (SIGW)               | NC F (SIGW)<br>X 1000V |
| 10.                              | 0.             | 0.1594628E-04          | 0.                     |
| 15.                              | 0.4392395E-22  | 0.2449926E-05          | 0.1553958E-21          |
| 20.                              | 0.2190014E-13  | 0.1086651E-05          | 0.3436544E-13          |
| 22.                              | 0.1912570E-11  | 0.7369660E-06          | 0.2035400E-11          |
| 24.                              | 0.5731040E-10  | 0.4816636E-06          | 0.3986278E-10          |
| 26.                              | 0.8082385E-09  | 0.3033744E-06          | 0.3540816E-09          |
| 28.                              | 0.6600714E-08  | 0.1841420E-06          | 0.1755209E-08          |
| 30.                              | 0.3593097E-07  | 0.1077124E-06          | 0.5588814E-08          |
| 32.                              | 0.1438104E-06  | 0.6071798E-07          | 0.1260935E-07          |
| 34.                              | 0.4539660E-06  | 0.3298434E-07          | 0.2162300E-07          |
| 36.                              | 0.1189647E-05  | 0.1726780E-07          | 0.2966472E-07          |
| 38.                              | 0.2688633E-05  | 0.8711743E-08          | 0.3382373E-07          |
| 40.                              | 0.5393723E-05  | 0.4235571E-08          | 0.3299024E-07          |
| 45.                              | 0.2086166E-04  | 0.5938290E-09          | 0.1788938E-07          |
| 50.                              | 0.5490881E-04  | 0.6607368E-10          | 0.5239084E-08          |
| 55.                              | 0.1123830E-03  | 0.5834627E-11          | 0.9468880E-09          |
| 60.                              | 0.1938156E-03  | 0.4088984E-12          | 0.1144430E-09          |
| 65.                              | 0.2962882E-03  | 0.2274234E-13          | 0.9730483E-11          |
| 70.                              | 0.4150862E-03  | 0.1003859E-14          | 0.6017219E-12          |
| 75.                              | 0.5451336E-03  | 0.3516637E-16          | 0.2768314E-13          |
| 80.                              | 0.6818978E-03  | 0.9776875E-18          | 0.9627295E-15          |

TABLE 21. EXCEEDANCES PER HOUR - CONDITION 9

7200 CONDITION 9 VERTICAL GUST ANALYSIS

WING ETA STATION = 0.33 STRUCTURAL ELEMENT 110

TURBULENCE PARAMETERS

P1 = 0.007000  
P2 = 0.000108  
B1 = 3.050000  
B2 = 9.370000

IG STRESSES (PSI)

| SHEAR   | SKIN     | SEGMENT  |
|---------|----------|----------|
| -1667.0 | -12830.0 | -12260.0 |

V TRUE (FT/SEC) = 802.3

G BAR = 0.3465593E-07 PER HOUR

| RMS<br>GUST VELOCITY<br>(FT/SEC) | NC<br>(PER FT) | F (SIGW)      | NC F(SIGW)<br>X 1000 |
|----------------------------------|----------------|---------------|----------------------|
| 10.                              | 0.             | 0.1368454E-04 | 0.                   |
| 15.                              | 0.2993697E-25  | 0.2563735E-05 | 0.1108322E-24        |
| 20.                              | 0.3589259E-15  | 0.9425586E-06 | 0.4885378E-15        |
| 22.                              | 0.6361527E-13  | 0.5841866E-06 | 0.5366583E-13        |
| 24.                              | 0.3263377E-11  | 0.3459464E-06 | 0.1630275E-11        |
| 26.                              | 0.6929357E-10  | 0.1957401E-06 | 0.1975613E-10        |
| 28.                              | 0.7948520E-09  | 0.1058192E-06 | 0.1214607E-09        |
| 30.                              | 0.5849825E-08  | 0.5465913E-07 | 0.4459463E-09        |
| 32.                              | 0.2812487E-07  | 0.2697582E-07 | 0.1095598E-08        |
| 34.                              | 0.1063578E-06  | 0.1272037E-07 | 0.1953685E-08        |
| 36.                              | 0.3247319E-06  | 0.5731121E-08 | 0.2683369E-08        |
| 38.                              | 0.8327842E-06  | 0.2467133E-08 | 0.2966948E-08        |
| 40.                              | 0.1863406E-05  | 0.1014751E-08 | 0.2730561E-08        |
| 45.                              | 0.8909196E-05  | 0.9020098E-10 | 0.1160471E-08        |
| 50.                              | 0.2728715E-04  | 0.6031117E-11 | 0.2376517E-09        |
| 55.                              | 0.6247506E-04  | 0.3033334E-12 | 0.2736603E-10        |
| 60.                              | 0.1173313E-03  | 0.1147567E-13 | 0.1944361E-11        |
| 65.                              | 0.1916566E-03  | 0.3265664E-15 | 0.9038163E-13        |
| 70.                              | 0.2829674E-03  | 0.6790173E-17 | 0.2856417E-14        |
| 75.                              | 0.3876067E-03  | 0.1125550E-18 | 0.6299999E-16        |
| 80.                              | 0.5016712E-03  | 0.1363216E-20 | 0.9875717E-18        |

TABLE 22. EXCEEDANCES PER HOUR - CONDITION 9 (38,000 FT.)

|                                         |                |                        |                       |
|-----------------------------------------|----------------|------------------------|-----------------------|
| 7200 CONDITION 9 VERTICAL GUST ANALYSIS |                |                        |                       |
| WING STA. STATION = 0.33                |                | STRUCTURAL ELEMENT 110 |                       |
| ALTITUDE 38,000 FT.                     |                |                        |                       |
| TURBULENCE PARAMETERS                   |                |                        |                       |
| P1 = 0.008300                           |                |                        |                       |
| P2 = 0.000100                           |                |                        |                       |
| B1 = 2.500000                           |                |                        |                       |
| B2 = 9.500000                           |                |                        |                       |
| IG STRESSES (PSI)                       |                |                        |                       |
| SHEAR                                   |                | SKIN                   | SEGMENT               |
| -1667.0                                 |                | -12830.0               | -12260.0              |
| V TRUE (FT/SEC) = 402.3                 |                |                        |                       |
| G BAR = 0.4021656E-07 PER HOUR          |                |                        |                       |
| RMS<br>GUST VELOCITY<br>(FT/SEC)        | NC<br>(PER FT) | F (SIGW)               | NC F(SIGW)<br>X 1800V |
| 10.                                     | 0.             | 0.1200366E-04          | 0.                    |
| 15.                                     | 0.2993697E-25  | 0.2420095E-05          | 0.1046225E-24         |
| 20.                                     | 0.3589759E-15  | 0.9157799E-06          | 0.4746581E-15         |
| 22.                                     | 0.6361527E-13  | 0.5750183E-06          | 0.5282360E-13         |
| 24.                                     | 0.3263377E-11  | 0.3454012E-06          | 0.1627706E-11         |
| 26.                                     | 0.6989357E-10  | 0.1984803E-06          | 0.2003271E-10         |
| 28.                                     | 0.7948520E-09  | 0.1091095E-06          | 0.1252373E-09         |
| 30.                                     | 0.5649825E-08  | 0.5737982E-07          | 0.4681436E-09         |
| 32.                                     | 0.2812489E-07  | 0.2886738E-07          | 0.1172419E-08         |
| 34.                                     | 0.1063578E-06  | 0.1389335E-07          | 0.2133836E-08         |
| 36.                                     | 0.3242319E-06  | 0.6396730E-08          | 0.2995013E-08         |
| 38.                                     | 0.8327842E-06  | 0.2817478E-08          | 0.3388270E-08         |
| 40.                                     | 0.1863406E-05  | 0.1187175E-08          | 0.3194532E-08         |
| 45.                                     | 0.8909196E-05  | 0.1127036E-09          | 0.1449977E-08         |
| 50.                                     | 0.2728715E-04  | 0.8110684E-11          | 0.3195954E-09         |
| 55.                                     | 0.6247506E-04  | 0.4424601E-12          | 0.3991772E-10         |
| 60.                                     | 0.1173313E-03  | 0.1829732E-13          | 0.3100176E-11         |
| 65.                                     | 0.1916566E-03  | 0.5735850E-15          | 0.1587473E-12         |
| 70.                                     | 0.2829674E-03  | 0.1363028E-16          | 0.5569628E-14         |
| 75.                                     | 0.3876062E-03  | 0.2455324E-18          | 0.1374309E-15         |
| 80.                                     | 0.5016712E-03  | 0.3352815E-20          | 0.2428922E-17         |



TABLE 23. EXCEEDANCES PER HOUR - CONDITION 10

## 7200 CONDITION 10. VERTICAL GUST ANALYSIS

WING ERA STATION = 0.33 STRUCTURAL ELEMENT 110

## TURBULENCE PARAMETERS

$P1 = 0.010500$   
 $P2 = 0.000090$   
 $B1 = 2.950000$   
 $B2 = 9.850000$

## IG STRESSES (PSI)

| SHEAR   | SKIN     | SEGMENT  |
|---------|----------|----------|
| -1680.0 | -12440.0 | -11890.0 |

V TRUE (FT/SEC) = 802.3

G BAR = 0.9421857E-07 PER HOUR

| RMS<br>GUST VELOCITY<br>(FT/SEC) | NC<br>(PER FT) | F (SIGW)      | NC F (SIGW)<br>X 1000V |
|----------------------------------|----------------|---------------|------------------------|
| 10.                              | 0.             | 0.1343433E-04 | 0.                     |
| 15.                              | 0.6825464E-24  | 0.2293402E-05 | 0.2260463E-23          |
| 20.                              | 0.1980235E-24  | 0.9279008E-06 | 0.2653404E-14          |
| 22.                              | 0.2562953E-12  | 0.6018662E-06 | 0.2227540E-12          |
| 24.                              | 0.1034991E-10  | 0.3746223E-06 | 0.5599060E-11          |
| 26.                              | 0.1839855E-09  | 0.2237600E-06 | 0.5944988E-10          |
| 28.                              | 0.1804632E-08  | 0.1282526E-06 | 0.3342257E-09          |
| 30.                              | 0.1138379E-07  | 0.7054160E-07 | 0.1159624E-08          |
| 32.                              | 0.5139145E-07  | 0.3723226E-07 | 0.2763091E-08          |
| 34.                              | 0.1792147E-06  | 0.1885769E-07 | 0.4880306E-08          |
| 36.                              | 0.5104520E-06  | 0.9165430E-08 | 0.6756048E-08          |
| 38.                              | 0.1237806E-05  | 0.4274765E-08 | 0.7640991E-08          |
| 40.                              | 0.2636902E-05  | 0.1913228E-08 | 0.7285271E-08          |
| 45.                              | 0.1145940E-04  | 0.2140765E-09 | 0.3542549E-08          |
| 50.                              | 0.3278019E-04  | 0.1851253E-10 | 0.8763187E-09          |
| 55.                              | 0.7135182E-04  | 0.1237248E-11 | 0.1274814E-09          |
| 60.                              | 0.1289484E-03  | 0.6390609E-13 | 0.1189989E-10          |
| 65.                              | 0.2044269E-03  | 0.2551068E-14 | 0.7530868E-12          |
| 70.                              | 0.2547557E-03  | 0.7870392E-16 | 0.3349991E-13          |
| 75.                              | 0.3961485E-03  | 0.1876571E-17 | 0.1073515E-14          |
| 80.                              | 0.5049039E-03  | 0.3458024E-19 | 0.2521283E-16          |

TABLE 24. EXCEEDANCES PER HOUR - CONDITION 11

|                                  |                |                        |                        |
|----------------------------------|----------------|------------------------|------------------------|
| 7200 CONDITION 11                |                | VERTICAL GUST ANALYSIS |                        |
| WING-ETA STATION = 0.33          |                | STRUCTURAL ELEMENT 110 |                        |
| TURBULENCE PARAMETERS            |                |                        |                        |
| P1 = 0.010500                    |                |                        |                        |
| P2 = 0.000090                    |                |                        |                        |
| B1 = 2.950000                    |                |                        |                        |
| B2 = 5.850000                    |                |                        |                        |
| IG STRESSES (PSI)                |                |                        |                        |
| SHEAR                            |                | SKIN                   | SEGMENT                |
| -1688.0                          |                | -12290.0               | -11740.0               |
| V TRUE (FT/SEC) = 402.3          |                |                        |                        |
| G RAR = 0.1386928E-06 PER HOUR   |                |                        |                        |
| RMS<br>GUST VELOCITY<br>(FT/SEC) | NC<br>(PER FT) | F (SIGN)               | NC F (SIGN)<br>X 1000V |
| 10.                              | 0.             | 0.1343433E-04          | 0.                     |
| 15.                              | 0.1018789E-22  | 0.2293402E-05          | 0.3374035E-22          |
| 20.                              | 0.8984191E-14  | 0.9279008E-06          | 0.1203831E-13          |
| 22.                              | 0.6878843E-12  | 0.6018662E-06          | 0.7716872E-12          |
| 24.                              | 0.2920107E-10  | 0.3746223E-06          | 0.1579710E-10          |
| 26.                              | 0.4424843E-09  | 0.2237600E-06          | 0.1429767E-09          |
| 28.                              | 0.3824009E-08  | 0.1282526E-06          | 0.7082233E-09          |
| 30.                              | 0.2178173E-07  | 0.7054160E-07          | 0.2218827E-08          |
| 32.                              | 0.9045698E-07  | 0.3723226E-07          | 0.4863472E-08          |
| 34.                              | 0.2943696E-06  | 0.1885769E-07          | 0.8016161E-08          |
| 36.                              | 0.7912543E-06  | 0.9165430E-08          | 0.1047258E-07          |
| 38.                              | 0.1826548E-05  | 0.4274765E-08          | 0.1127777E-07          |
| 40.                              | 0.3732443E-05  | 0.1913228E-08          | 0.1031205E-07          |
| 45.                              | 0.1495351E-04  | 0.2140765E-09          | 0.4622716E-08          |
| 50.                              | 0.4035565E-04  | 0.1851253E-10          | 0.1078835E-08          |
| 55.                              | 0.8413070E-04  | 0.1237248E-11          | 0.1503132E-09          |
| 60.                              | 0.1471225E-03  | 0.6390609E-13          | 0.1357708E-10          |
| 65.                              | 0.2273304E-03  | 0.2551068E-14          | 0.8374610E-12          |
| 70.                              | 0.3211684E-03  | 0.7870397E-16          | 0.3650179E-13          |
| 75.                              | 0.4246314E-03  | 0.1876571E-17          | 0.1150700E-14          |
| 80.                              | 0.5340711E-03  | 0.3458024E-19          | 0.2666932E-16          |

TABLE 25. EXCEEDANCES PER HOUR - CONDITION 12

|                                          |                |                        |                        |
|------------------------------------------|----------------|------------------------|------------------------|
| 220R CONDITION 12 VERTICAL GUST ANALYSIS |                |                        |                        |
| WING ETA STATION = 0.33                  |                | STRUCTURAL ELEMENT 110 |                        |
| TURBULENCE PARAMETERS                    |                |                        |                        |
| P1 = 0.100000                            |                |                        |                        |
| P2 = 0.000600                            |                |                        |                        |
| R1 = 3.550000                            |                |                        |                        |
| R2 = 9.700000                            |                |                        |                        |
| IG STRESSES (PSI)                        |                |                        |                        |
| SHEAR                                    |                | SKIN                   | SEGMENT                |
| -2322.0                                  |                | -10730.0               | -10250.0               |
| V TRUE (FT/SEC) = 523.6                  |                |                        |                        |
| G BAR = 0.7597590E-06 PER HOUR           |                |                        |                        |
| RMS<br>GUST VELOCITY<br>(FT/SEC)         | NC<br>(PER FT) | F (SIGM)               | NC F (SIGM)<br>X 1000V |
| 10.                                      | 0.             | 0.4542770E-03          | 0.                     |
| 15.                                      | 0.1561897E-22  | 0.1791400E-04          | 0.2636922E-21          |
| 20.                                      | 0.1380613E-13  | 0.5893658E-05          | 0.7668476E-13          |
| 22.                                      | 0.1371655E-11  | 0.3769846E-05          | 0.4873272E-11          |
| 24.                                      | 0.4532674E-10  | 0.2312003E-05          | 0.9876321E-10          |
| 26.                                      | 0.6896673E-09  | 0.1358943E-05          | 0.8832692E-09          |
| 28.                                      | 0.5981280E-08  | 0.7655112E-06          | 0.4315169E-08          |
| 30.                                      | 0.3417333E-07  | 0.4132748E-06          | 0.1331001E-07          |
| 32.                                      | 0.1422918E-06  | 0.2138274E-06          | 0.2867447E-07          |
| 34.                                      | 0.4661149E-06  | 0.1040290E-06          | 0.4637700E-07          |
| 36.                                      | 0.1250027E-05  | 0.5038757E-07          | 0.5936015E-07          |
| 38.                                      | 0.2891313E-05  | 0.2294875E-07          | 0.6253258E-07          |
| 40.                                      | 0.5916142E-05  | 0.1001686E-07          | 0.5584792E-07          |
| 45.                                      | 0.2377751E-04  | 0.1046859E-08          | 0.2345884E-07          |
| 50.                                      | 0.6432291E-04  | 0.8387859E-10          | 0.5084743E-08          |
| 55.                                      | 0.1343430E-03  | 0.5152532E-11          | 0.6523609E-09          |
| 60.                                      | 0.2352751E-03  | 0.2426593E-12          | 0.5380531E-10          |
| 65.                                      | 0.3640106E-03  | 0.8761528E-14          | 0.3005703E-11          |
| 70.                                      | 0.5149513E-03  | 0.2425321E-15          | 0.1177030E-12          |
| 75.                                      | 0.6819313E-03  | 0.5147134E-17          | 0.3307945E-14          |
| 80.                                      | 0.8594628E-03  | 0.8374681E-19          | 0.6783407E-16          |

TABLE 26 (a)  
 EXCEEDANCES OF LIMIT STRENGTH PER AVERAGE FLIGHT HOUR  
 FOR TOTAL AIRPLANE USAGE,  $N_p$   
 VERTICAL ANALYSIS, WING

| Component | Station    | Structural<br>Element | $N_p$                 |
|-----------|------------|-----------------------|-----------------------|
| Wing      | Eta<br>.33 | 0                     | $2.5 \times 10^{-8}$  |
|           |            | 1                     | $1.0 \times 10^{-8}$  |
|           |            | 7                     | $1.1 \times 10^{-6}$  |
|           |            | 9                     | $2.1 \times 10^{-6}$  |
|           |            | 17                    | $1.5 \times 10^{-7}$  |
|           |            | 99                    | $9.1 \times 10^{-9}$  |
|           |            | 100                   | $3.5 \times 10^{-11}$ |
|           |            | 101                   | $6.7 \times 10^{-10}$ |
|           |            | 110                   | $1.1 \times 10^{-6}$  |
|           |            | 117                   | $2.3 \times 10^{-5}$  |
|           |            | 122                   | $6.5 \times 10^{-6}$  |
|           |            | 199                   | $9.1 \times 10^{-8}$  |

TABLE 26 (b)

EXCEEDANCES OF LIMIT STRENGTH PER AVERAGE FLIGHT HOUR  
FOR TOTAL AIRPLANE USAGE,  $N_p$  -  
VERTICAL ANALYSIS, FUSELAGE

| Component | Station      | Structural<br>Element | $N_p$            |
|-----------|--------------|-----------------------|------------------|
| Fuselage  | Body<br>540  | 100                   | $1.2(10^{-11})$  |
|           |              | 2                     | $1.7(10^{-11})$  |
|           |              | 3                     | $2.3(10^{-11})$  |
|           |              | 4                     | $9.1(10^{-11})$  |
|           |              | 8                     | $9.0(10^{-10})$  |
|           |              | 9                     | $2.0(10^{-9})$   |
|           |              | 16                    | $6.9(10^{-13})$  |
|           |              | 20                    | $5.1(10^{-12})$  |
|           |              | 23                    | $3.0(10^{-13})$  |
|           |              | 2700                  | $2.9(10^{-11})$  |
|           |              | 28                    | $3.1(10^{-16})$  |
|           |              | 29                    | $2.9(10^{-14})$  |
|           |              | 30                    | $1.1(10^{-10})$  |
|           | Body<br>1040 | 100                   | $3.0(10^{-15})$  |
|           |              | 2                     | $2.1(10^{-14})$  |
|           |              | 3                     | $8.0(10^{-14})$  |
|           |              | 4                     | $9.3(10^{-14})$  |
|           |              | 8                     | $3.5(10^{-15})$  |
|           |              | 16                    | $3.5(10^{-11})$  |
|           |              | 20                    | $10.0(10^{-15})$ |
|           |              | 23                    | $3.3(10^{-27})$  |
|           |              | 27                    | $5.4(10^{-21})$  |
|           |              | 28                    | $1.8(10^{-11})$  |
|           | Body<br>1360 | 100                   | $1.02(10^{-14})$ |
|           |              | 2                     | $2.6(10^{-14})$  |
|           |              | 3                     | $1.1(10^{-14})$  |
|           |              | 4                     | $3.4(10^{-15})$  |
|           |              | 8                     | $5.6(10^{-21})$  |
|           |              | 1200                  | $2.0(10^{-48})$  |
|           |              | 14                    | $8.2(10^{-31})$  |
|           |              | 16                    | $2.2(10^{-20})$  |
|           |              | 23                    | $7.8(10^{-17})$  |
|           |              | 27                    | $1.8(10^{-15})$  |
|           |              | 28                    | $1.6(10^{-15})$  |
|           |              | 29                    | $1.9(10^{-16})$  |
|           |              | 31                    | $2.7(10^{-12})$  |

**TABLE 26 (c)**  
**EXCEEDANCES OF LIMIT STRENGTH PER AVERAGE FLIGHT HOUR**  
**FOR TOTAL AIRPLANE USAGE,  $N_p$  -**  
**LATERAL ANALYSIS**

| Component | Station                | Structural Element | $N_p$           |                 |
|-----------|------------------------|--------------------|-----------------|-----------------|
|           |                        |                    | Yaw Damper On   | Yaw Damper Off  |
| Fuselage  | Body<br>1040           | 100                | $9.1(10^{-13})$ | $3.4(10^{-10})$ |
|           |                        | 2                  | $1.2(10^{-12})$ | $4.0(10^{-10})$ |
|           |                        | 3                  | $9.5(10^{-13})$ | $7.1(10^{-10})$ |
|           |                        | 4                  | $8.5(10^{-14})$ | $1.5(10^{-10})$ |
|           |                        | 8                  | $9.9(10^{-13})$ | $5.4(10^{-10})$ |
|           |                        | 16                 | $8.1(10^{-13})$ | $3.7(10^{-10})$ |
|           |                        | 20                 | $3.5(10^{-12})$ | $6.3(10^{-11})$ |
|           |                        | 23                 | $1.6(10^{-27})$ | $1.7(10^{-19})$ |
|           |                        | 27                 | $6.4(10^{-32})$ | $3.2(10^{-22})$ |
|           |                        | 28                 | $2.3(10^{-23})$ | $1.0(10^{-16})$ |
|           | Body<br>1360           | 100                | $4.8(10^{-19})$ | $2.2(10^{-13})$ |
|           |                        | 2                  | $2.0(10^{-19})$ | $1.8(10^{-13})$ |
|           |                        | 3                  | $4.8(10^{-16})$ | $1.6(10^{-11})$ |
|           |                        | 4                  | $1.2(10^{-13})$ | $6.8(10^{-10})$ |
|           |                        | 8                  | $6.9(10^{-11})$ | $7.5(10^{-8})$  |
|           |                        | 1200               | $4.3(10^{-10})$ | $2.1(10^{-7})$  |
|           |                        | 14                 | $5.5(10^{-9})$  | $1.4(10^{-6})$  |
|           |                        | 16                 | $2.1(10^{-8})$  | $3.5(10^{-6})$  |
|           |                        | 23                 | $9.6(10^{-9})$  | $1.1(10^{-6})$  |
|           |                        | 27                 | $3.0(10^{-10})$ | $3.2(10^{-7})$  |
| Fin       | Elastic<br>Axis<br>158 | 28                 | $2.1(10^{-9})$  | $4.4(10^{-7})$  |
|           |                        | 29                 | $1.1(10^{-10})$ | $6.0(10^{-8})$  |
|           |                        | 3100               | $3.1(10^{-11})$ | $9.8(10^{-8})$  |
|           |                        | 0                  | $2.6(10^{-9})$  | $8.0(10^{-6})$  |
|           |                        | 1                  | $4.7(10^{-9})$  | $1.3(10^{-6})$  |
|           |                        | 5                  | $1.0(10^{-12})$ | $7.6(10^{-9})$  |
|           |                        | 10                 | $9.8(10^{-15})$ | $5.2(10^{-10})$ |
|           |                        | 110                | $2.4(10^{-16})$ | $3.9(10^{-11})$ |
|           |                        | 100                | $4.7(10^{-9})$  | $1.7(10^{-6})$  |

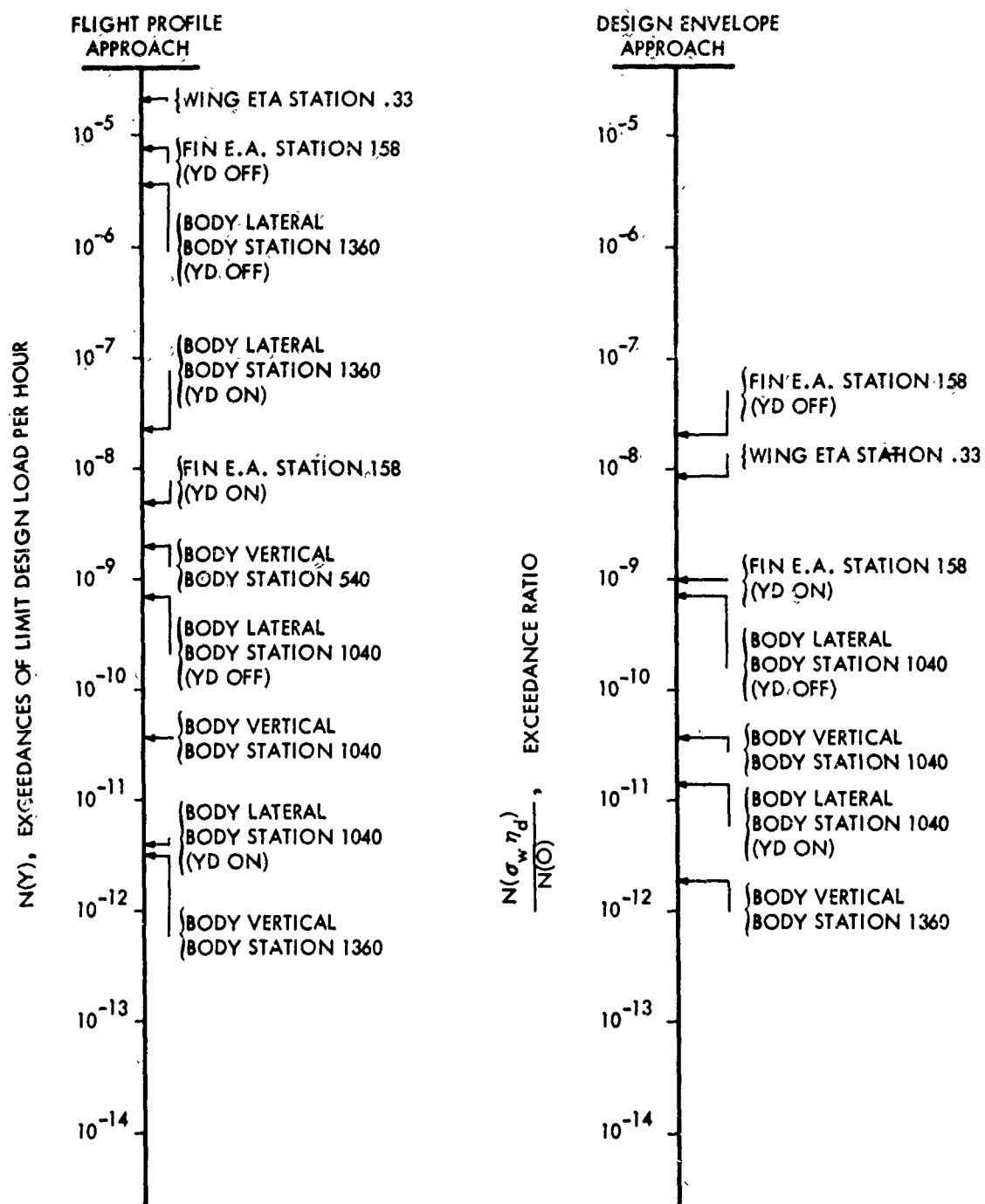


FIGURE 84. SUMMARY OF DESIGN VALUES OF EXCEEDANCE RATIOS AND FREQUENCY OF EXCEEDANCES BASED ON JOINT PROBABILITY

## CONCLUSIONS

### General

The use of power spectral techniques to assess the strength capability of airplanes subjected to continuous turbulence appears to be the most rational approach to the airplane gust design problem. The statistical methods which were developed basically in the communications field are well founded and understood; however, their application to complex aircraft structure in dynamic loads analyses has only been pursued in recent years.

There are two rather general problems associated with a detailed gust power spectral analyses. The first is the "long chain" of calculations that must be conducted to arrive at the solution, and the second is the interpretation of the statistical result in terms that are meaningful to the design engineer. In the foregoing analysis, the first problem was partially overcome by proper linking of the individual digital computer programs required to calculate the dynamic responses in the flexible modes, the rms loads and stresses, and finally the statistical results into a chain program. This allowed for orderly flow of data by the use of tape storage from one program to another. This enables an engineer to analyze many conditions in a relatively short period of time. The results of this study will serve as a guide to the solution of the second problem.

Dynamic analyses leading up to an assessment of the strength of structural elements or components is complex and can be very sensitive to the mathematical description of the airplane being analyzed. Even when the analysis is conducted for an airplane that is currently in service, a vehicle for which a great deal of information is available, the analysis is still difficult to accomplish. Experienced personnel who are capable of exercising good judgment on estimates of sensitive airplane parameters are needed to use this approach in the preliminary design stage.

Certainly, power spectral gust analyses should be conducted early in the design stages to "raise-the-flag" on possible problem areas. Furthermore, these analyses should include parametric variations of sensitive parameters, which need better definition. The analyses may become more complex as the design nears the final stages, but the analysis should be assessed in each stage by comparing reduced solutions of the basic equations with separate maneuver and flutter solutions.



### One Parameter Versus Joint Probability Approaches

If the structure being analyzed is sensitive primarily to an axial stress which results predominantly from bending, the bending moment approach and the joint probability approach should lead to nearly the same result. This is true, because the other load quantities contribute only slightly to the margin of safety in the more critical structural elements. Since the effort involved in a single parameter bending moment approach is about one-half of that of the full joint probability stress analysis, it is advantageous to use a bending moment criteria when suitable.

The bending moment analysis is useful in the design envelope approach to help locate the critical flight condition. The selection of critical conditions for vertical analyses in this program required 20 separate analyses. If all of these analyses had been carried through the joint probability solution, the analyses time would have been extended several months. Since all of the load quantities tended to increase as the critical condition was approached, the bending moment served as a good measure of the criticalness of the condition.

The success of using the bending moment to locate the critical structure is dependent again upon whether or not the structural element is more likely to reach limit load under an axial stress condition or a combined stress condition. If it is a stress condition which results from combined loadings then the bending moment alone will lead to erroneous results.

The joint probability method, while more rational in considering combined loading, has some drawbacks in regards to its use in a design sense. One of these problems is in obtaining the detailed stress coefficients, another is the definition of the strength envelope.

### Model 720B Analysis Results

Limit-strength values of  $\sigma_w \eta_d$  and of hours to exceed limit design strength, for the model 720B, are summarized in Figures 85 and 86. Results based on both the bending moment analyses and the more exact joint probability analyses are shown.

### Recommendations for Design

Specifically, the following recommendations are offered concerning the use of gust power spectral techniques in airplane design:

1. Gust power spectral analysis techniques appear to be the most rational approach to the gust loads design problem. However, they should be used in such a manner that they can truly assure timely design information, and hence a properly designed airplane from the standpoint of gust loading. This can be

accomplished by a continual study during the airplane design stages using the best available data at each stage to eliminate the possibility of unpleasant surprises after the airplane is in service.

2. Initially, the aerodynamic, structural, and stability augmentation data used in the analyses will be rough; therefore, these initial analyses should be simple and should include parametric variations on the more significant input data.
3. Then, the more sensitive parameters should be isolated and studied further through separate test and analysis programs.
4. Later studies will be used to evaluate the limit bending moments, shears, and torsions for the major components. Also, the phasing or correlation between these loads should be obtained and used as a guide in the design.
5. Joint probability techniques to properly account for the phasing of the loads or stresses should be employed only for the more critical components of the airplane when the margin of safety is highly dependent on combined loading and the statistical correlation between the loads or the stresses is poor.
6. All of the studies should be subjected to a set of checks with separate maneuver and flutter analyses or test results in order to keep the studies in perspective and to provide confidence in the results as the analyses become more complex during the later design stages.
7. Stability augmentation systems and control dynamic effects should be incorporated in the early studies and developed along with the basic airframe in coupled dynamic loads gust analyses.

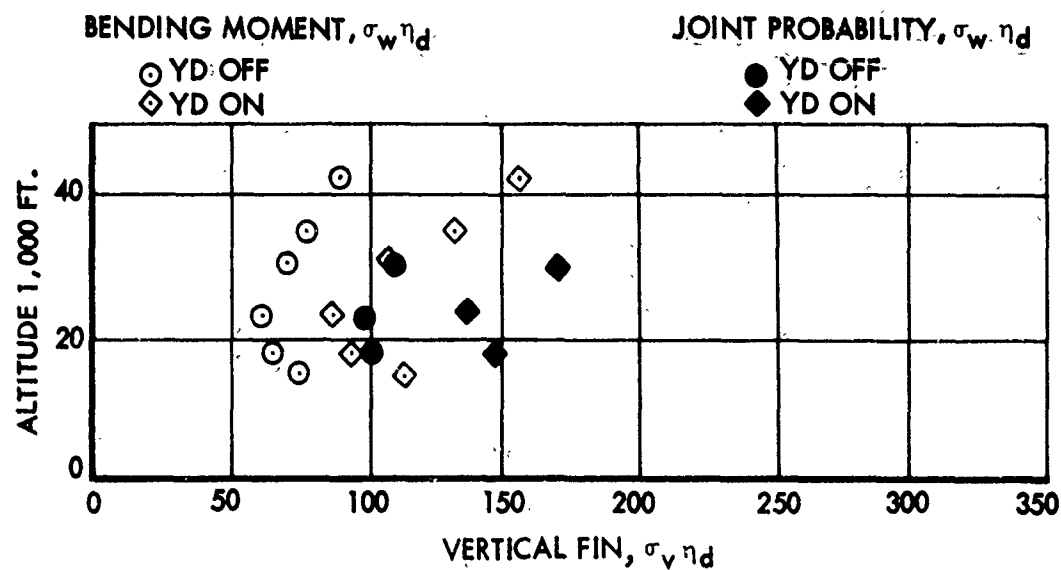
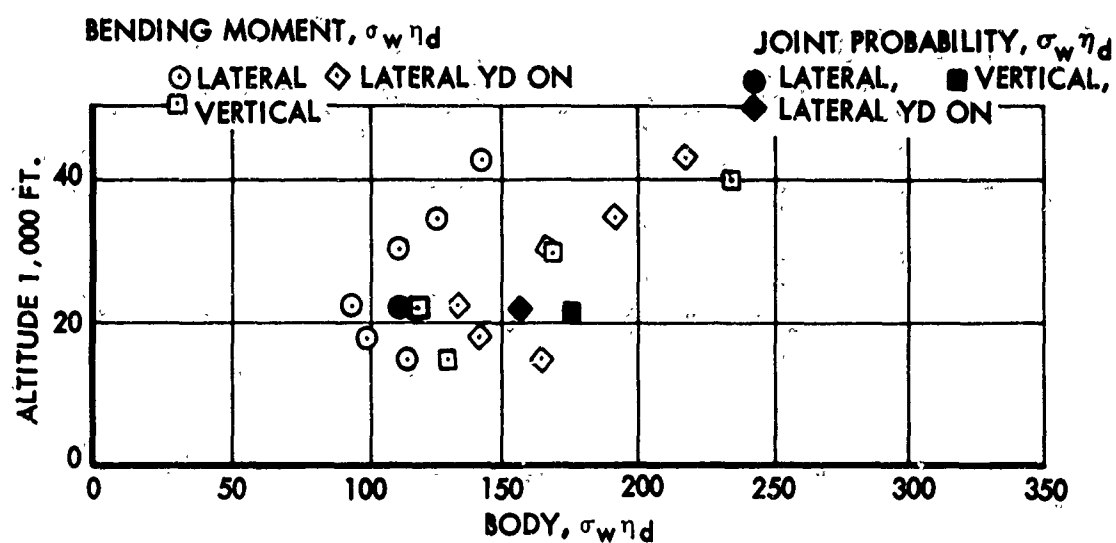
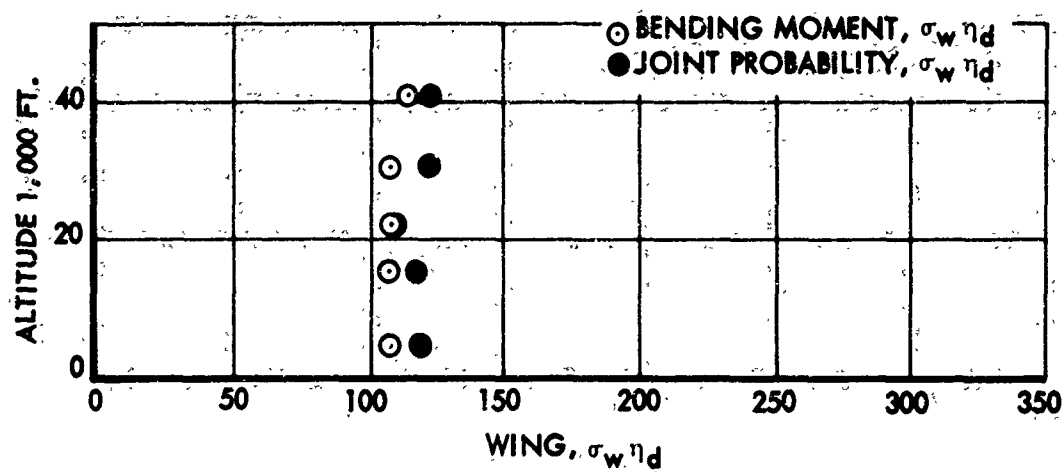


FIGURE 85. SUMMARY OF CRITICAL VALUES OF  $\sigma_w \eta_d$

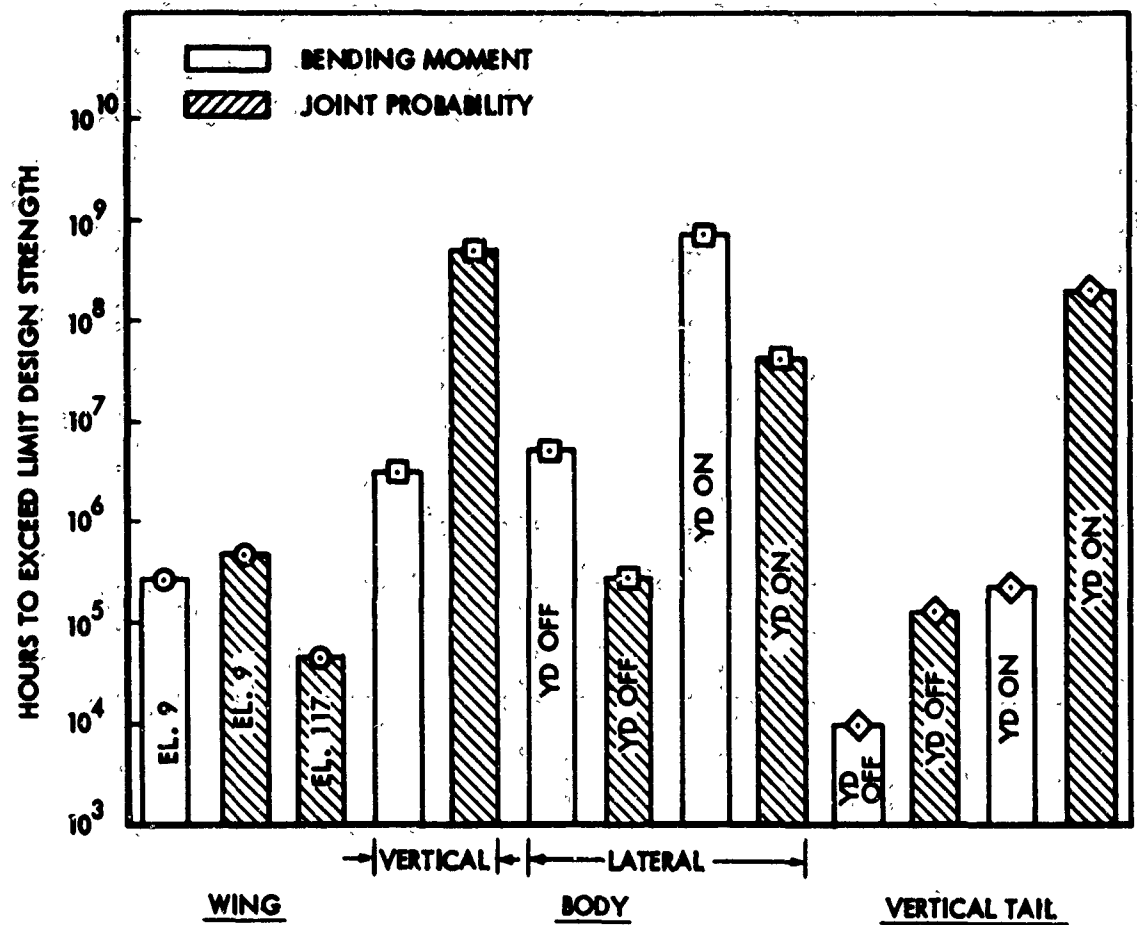


FIGURE 86. SUMMARY OF FLIGHT PROFILE RESULTS

APPENDIX A  
EQUATIONS OF MOTION

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APPENDIX A  
EQUATIONS OF MOTION

General Comments

The degree of success in evaluating the strength capability of a complex airplane structure subjected to flight in atmospheric turbulence relies almost entirely upon the ability to construct a mathematical model of the physical system. An airplane in flight is considered to be an elastic-dynamic system which when acted upon by external aerodynamic gust velocities undergoes motions necessary to maintain an energy balance. The analysis procedure generally used is referred to as the Energy Method and is applicable to a system where the total change in kinetic energy is equal to the summation of the work done by all forces acting during a slight deflection from the equilibrium position. In other words the application of the energy method is contingent on the principle of virtual work which may be stated as follows:

If a body is in equilibrium under the action of prescribed external forces, the work done by these forces in a small additional displacement compatible with the constraints is equal to the change in strain energy.

The above statement can be expressed as Eq. (A1)

$$\delta W_e + \delta W_{in} = \delta V \quad (A1)$$

where

$\delta W_e$  = the external work done

$\delta W_{in}$  = the internal work done

$\delta V$  = the change in strain energy

The airplane motions, as given by Eq. (A2), are expressed as the summation over a set of independent generalized coordinates which are defined explicitly in terms of space and time.

$$\delta_i = \sum_{j=1}^n \phi_{ij} q_j \quad (A2)$$

where

$\phi_{ij}$  = the jth normalized mode shape which is a function of geometry only.

$q_j$  = the jth generalized coordinate which is a function of time only.

Using the above coordinate definition and Lagrange's specialized form of the energy equation, the equations of motion for the physical system are formed using Eq. (A3).

$$\left[ \frac{d}{dt} \left( \frac{\partial T}{\partial \dot{q}_j} \right) - \frac{\partial T}{\partial q_j} + \frac{\partial V}{\partial q_j} \right] \delta q_j + Q_j \delta q_j = \bar{Q}_j \phi_{aj} \quad (A3)$$

where

$T$  = the kinetic energy of the system.

$V$  = the strain energy of the system.

$Q_j$  = generalized external force due to the system's response.

$\bar{Q}_j$  = generalized external force due to the gust velocity.

$q_j$  = the jth generalized coordinate displacement.

$\dot{q}_j$  = the jth generalized coordinate velocity.

For a linear elastic system such as the airplane structure the elastic forces are given by  $\partial V / \partial q_j$  and the kinetic energy is not dependent upon the displacement,  $q_j$ , thus  $\partial T / \partial q_j = 0$ , leaving the Lagrangian equation as Eq. (A4) below.

$$\left[ \frac{d}{dt} \left( \frac{\partial T}{\partial \dot{q}_j} \right) + \frac{\partial V}{\partial q_j} + Q_j \right] \delta q_j = \bar{Q}_j \phi_{aj} \quad (A4)$$

## VERTICAL ANALYSES

### Generalized Inertia

The kinetic energy,  $T$ , in the above equation is obtained by multiplying the individual lumped masses by their respective velocities squared and then summing over the generalized coordinates. This can be expressed in matrix form as Eq. (A5).

$$\left[ \dot{q}_j \right] \left[ \phi_{ij} \right] \left[ a_{ri} \right] \left[ M_{rr} \right] \left[ a_{ri} \right] \left[ \phi_{ij} \right] \left[ \ddot{q}_j \right] = 2 T \quad (A5)$$

where

$\left[ M_{rr} \right]$  = the mass and inertia properties described about the principle axis at the lumped mass center of gravity.

$\left[ a_{ri} \right]$  = the transformation matrix transforming lumped mass center of gravity displacements to elastic axis displacements.

$\left[ \phi_{ij} \right]$  = the normalized mode shapes.

When this kinetic energy matrix,  $T$ , is substituted into Lagrange's equation and the appropriate differentiations carried out the following inertia matrix is generated:

$$\frac{d}{dt} \left[ \frac{\partial T}{\partial \dot{q}_j} \right] = \left[ M_3 \right] \left[ \ddot{q}_j \right] \quad (A6)$$

where

$$\left[ M_3 \right] = \left[ \phi_{ij} \right]^T \left[ J_{ii} \right] \left[ \phi_{ij} \right]$$

$\ddot{q}_j$  = generalized coordinate acceleration

$$\left[ J_{ii} \right] = \left[ a_{ri} \right]^T \left[ M_{rr} \right] \left[ a_{ri} \right]$$

as described above.

#### Generalized Stiffness

The second portion of equations of motion by the Lagrangian approach are the strain energy terms. The strain energy associated with a deflection in the generalized coordinates could be generated by considering the elastic axis as a series of springs having stiffnesses of  $k_i$ . Then the strain energy would be given by Eq. (A7).

$$2V = \left[ q_j \right] \left[ \phi_{ij} \right]^T \left[ k_{ii} \right] \left[ \phi_{ij} \right] \left[ q_j \right] \quad (A7)$$



and when substituted in Lagrange's equation would result as Eq. (A8)

$$\frac{\partial V}{\partial q_j} = [K_{jj}] [q_j] \quad (A8)$$

where

$$[K] = [\phi_{ij}] [k_{ii}] [\phi_{ij}]$$

However, it is more convenient to use the natural frequency of the jth normal mode to represent the generalized stiffness as expressed by Eq. (A9):

$$[M_3]_{jj} \omega_{n_j}^2 = [K_{jj}] \quad (A9)$$

A tabulation of the natural frequencies used in the analysis are given in Tables 6 and 7 in the Analysis Section.

#### Generalized Response Aerodynamics

The generalized external forces which result from the motion of the system,  $Q_j$ , are the aerodynamic lift and moments. These force expressions are based upon a modified strip theory (8) which incorporates the aerodynamic induction between the individual aerodynamic panels. The transmittal time associated with this aerodynamic induction is also incorporated as a phase lag between the resultant force vector and the originating panel motion. The strip theory coefficients which give the aerodynamic forces on a panel due to its own motion are used as they were originally expressed by Theodorsen (9) and Küssner (10) with two exceptions. These exceptions are the two dimensional lift and moment expressions,  $2\pi$ , and  $(1/2+a)$  are changed to values more representative of the aerodynamic surface being examined. The adjusted values are obtained by reducing the oscillatory lift and moment coefficients to their steady state values and using the static induction matrix (7) to solve for the lift and moment coefficients that give the proper steady state lift and moment distributions. These values are then used with the dynamic induction matrix and oscillatory lift and moment coefficients to give the generalized external aerodynamic force due to system response. A representative equation for this generalized external force is given below in matrix form as Eq. (A10):

$$[Q_j] = 2\rho b_r^2 \omega^2 [\phi_{ij}] \begin{bmatrix} [S_1^{-1} f(t)] \Delta x_i & 0 \\ T[S_1^{-1} f(t)] \Delta x_i & [S_1^{-1} f(t)] \Delta x_i \end{bmatrix} \begin{bmatrix} A_{Lh} & A_{La} \\ A_{mh} & A_{ma} \end{bmatrix} [\phi_{ij}] [q_j] \quad (A10)$$

wing  
tail

where

$\rho$  = atmospheric density - lb.sec.<sup>2</sup> per in.<sup>4</sup>

$b_r$  = reference semi-chord - in.

$\omega$  = response frequency - rad. per sec.

$\Delta x_i$  = span of the  $i$ th aerodynamic panel - in.

$T$  = distance from panel quarter chord to panel rotation axis - in.

$[S_1^{-1} f(t)]$  = dynamic induction matrix - in.

$A_{Lh}$  = oscillatory panel lift coefficient due to the translation motion of the panel rotation axis.

$A_{La}$  = oscillatory panel lift coefficient due to angular motion about the panel rotation axis.

$A_{mh}$  = oscillatory panel moment coefficient due to translation motion of the panel rotation axis.

$A_{ma}$  = oscillatory panel moment coefficient due to rotation motion about the panel rotation axis.

Selecting a frequency,  $\omega$ , the evaluation of the above generalized external force expression results in an aerodynamic matrix with complex coefficients. Since this expression is for a discrete harmonic frequency these complex coefficients can be expressed by Eq. (A11).

$$[a+ib] q_j = [a] q_j + \frac{1}{\omega} [b] \dot{q}_j \quad (A11)$$

where

$$q_j = q_{pj} e^{i\omega t}$$

$$\dot{q}_j = i\omega q_j$$

$$\ddot{q}_j = -\omega^2 q_j$$

Applying this to  $[Q_j]_{w\&T}$  in Eq. (A10) gives a set of aerodynamic coefficients for the generalized coordinate displacements and velocities as shown in Eq. (A12).

$$\left[ Q_j \right]_{W\&T} = \frac{1}{\omega} \left[ A_1 \right]_{W\&T} \dot{\phi}_j + \left[ A_2 \right]_{W\&T} \phi_j \quad (A12)$$

The aerodynamic forces acting upon the body panels are treated separately. Quasi-steady expressions are used which account for apparent angles of attack due to translation velocities, rotation displacements and rotational velocities of each body panel. The expression for these forces are given below in Eq. (A13).

$$\left[ Q_j \right]_B = 2\rho b_r^3 \omega^2 \left[ \phi_{ij} \right] \begin{bmatrix} \bar{A}_{Lh} & \bar{A}_{La} \\ \bar{A}_{mh} & \bar{A}_{ma} \end{bmatrix} \left[ \phi_{ij} \right] \dot{\phi}_j \quad (A13)$$

where

- $\bar{A}_{Lh}$  = quasi static lift coefficient due to translation
- $\bar{A}_{La}$  = quasi static lift coefficient due to rotation
- $\bar{A}_{mh}$  = quasi static moment coefficient due to translation
- $\bar{A}_{ma}$  = quasi static moment coefficient due to rotation

These are calculated for each frequency and converted to displacement and velocity coefficients and added the generalized forces calculated for the wing and horizontal tail to give total generalized external force due to system response.

#### Generalized Excitation Aerodynamics

The remaining external force arises from the turbulence velocities,  $U$ . The expressions used to describe this generalized force are similar to those used to describe the aerodynamic forces due to response. The only essential difference is that these forces arise from gust angles of attack. When employing the power spectral density approach, it is necessary to obtain the response of the airplane to discrete gust frequencies. These gust angle inputs are expressed by Eq. (A14).

$$a_g = \frac{U}{V_T} e^{i\omega t} \quad (A14)$$

- $U$  = gust velocity, usually taken as 1 ft. per sec.
- $V_T$  = true airplane velocity, ft. per sec.
- $\omega$  = gust excitation frequency, rad. per sec.

As the airplane penetrates the gust the excitation force is felt progressively along the direction of flight. The gradual penetration effect is represented as a phase lag by Eq. (A15).

$$a_g = \frac{U}{V_T} e^{i(\omega t + \theta)} \quad (A15)$$

where

$$\theta = \omega \frac{\lambda_1 + b_1}{V_T}$$

$\lambda_1 + b_1$  = the distance from the leading edge of the foremost panel to the mid-chord of panel 1.

Substituting the expression for  $\theta$  into Eq. (A15) gives Eq. (A16).

$$a_g = \frac{U}{V_T} e^{i\omega t} e^{\frac{i\omega(\lambda_1 + b_1)}{V_T}} \quad (A16)$$

The end expression for the generalized external force due to a sinusoidal gust velocity is given by Eq. (A17).

$$\left\{ \bar{Q}_j \right\} = 2\rho_b^3 \omega^2 \left[ \phi_{1j} \right] \left[ a_{1j} \right] \left[ S_1^{-1} f(t) \Delta x \right] \left[ \bar{A}_{Lg} \right] \frac{W}{V} e^{i\omega t} e^{\frac{i\omega(\lambda+b)}{V_T}} \quad (A17)$$

where

$$\left[ \bar{A}_{Lg} \right] = \text{modified two dimensional lift coefficient due to gust angle of attack.}$$

#### Structural Damping

The final item that may be included and is not shown in Lagrange's equation is the structural damping force. This force is assumed to be proportional to the generalized stiffness but in phase with the generalized coordinate velocity. An expression for this is shown below:

$$\text{structural damping} = i g_j k_j \dot{q}_j \quad (A18)$$

where

$g_j$  = damping coefficient approximately equal to twice the damping ratio  $c/c_c$ .

$i$  = phasing operator which shifts the force vector 90 degrees ahead of the displacement  $q_j$ .

$k_j$  = generalized stiffness for the  $j$ th mode.

The expression used in the equations of motion is given by the following form:

$$i g_j k_j q_j = \frac{g_j M_{3jj} \omega_{N_j}^2}{\omega} \dot{q}_j \quad (A19)$$

The equations of motion for the mathematical model of the airplane system are formed by collecting all of the above expressions into a matrix equation as follows:

$$\begin{aligned} [M_3] \ddot{q}_j + \frac{1}{\omega} \left\{ [A_1]_{W\&T} + [A_1]_B + [g_j M_{3jj} \omega_{N_j}^2] \right\} \dot{q}_j + \left\{ [A_2]_{W\&T} + [A_2]_B \right. \\ \left. + [M_{3jj} \omega_{N_j}^2] \right\} q_j = \frac{W}{V} [A_g] e^{\frac{i\omega(\lambda+b_1)}{V_T}} e^{i\omega t} \end{aligned} \quad (A20)$$

or simplified

$$[M_3] \ddot{q} + [M_2] \dot{q} + [M_1] q = \frac{W}{V} [C_3] e^{\frac{i\omega(\lambda+b_1)}{V_T}} e^{i\omega t} \quad (A21)$$

Substituting for  $\dot{q}$  and  $q$  under the assumption of harmonic motion as shown in Eq. (A11) we obtain

$$\left\{ -\omega^2 [M_3] + [M_1] + i\omega [M_2] \right\} q_{oj} = \frac{W}{V} [C_3] e^{\frac{i\omega(\lambda+b)}{V_T}} \quad (A22)$$

### Solution of Equations of Motion

The final step is the solving of the equations of motion to obtain the response of the generalized coordinate,  $q_{oj}$ . This solution, obtained for

each discrete frequency,  $\omega$  as shown by Eq. (A23), results in the vector magnitude and phase angle relative to the gust input of each of the generalized coordinates.

$$\dot{q}_{0j} = \left\{ \left[ -\omega^2 [M_3] + [M_1] \right] + i\omega [M_2] \right\}^{-1} \frac{W}{V} [C_3] e^{\frac{i\omega(\lambda+b)}{V_T}} \quad (A23)$$

Representative frequency response curves are shown in Fig. 27 of the Results section.

## LATERAL ANALYSES

### Areas of Similarity between Vertical and Lateral Analyses

The equations of motion for the lateral analyses are also formed using the Lagrangian approach. The formulation of the generalized inertia and stiffness matrices for the lateral equations of motion follow the same procedure as outlined for the vertical analyses. The generalized coordinates used in these lateral equations are the antisymmetric body and vertical tail cantilevered modes as listed in Table 8 of the Analyses Section.

### Generalized Aerodynamics

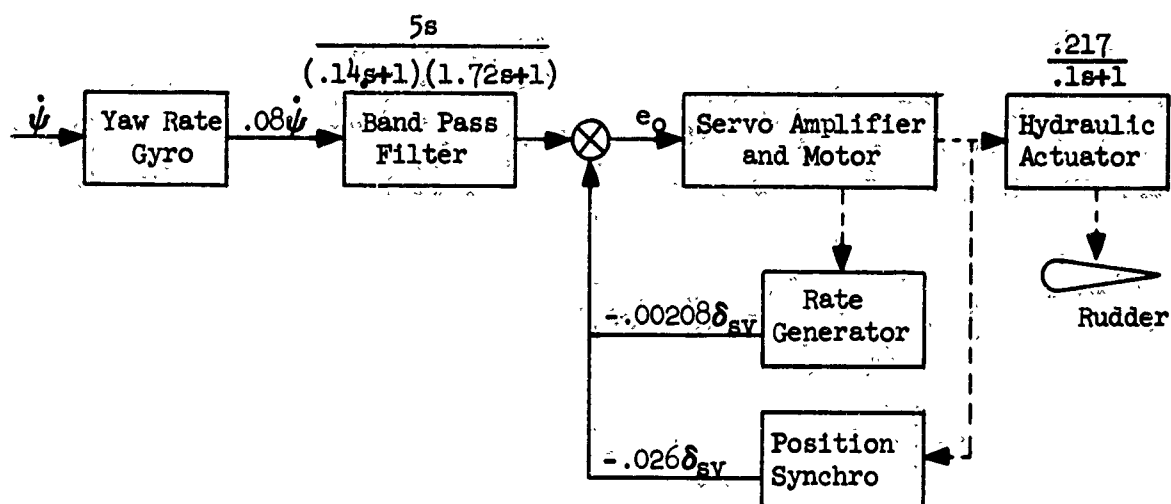
The aerodynamic response and excitation forces, however, are based on quasi-steady expressions which are convoluted with the Wagner and Küssner lift growth functions. The Wagner and Küssner lift growth effects were represented by the step response functions (recommended on Page 344, Ref. 18) for an aspect ratio of three. The frequency domain analysis requires that lift growth effects be represented by the impulse function which is obtained by writing the Laplace transform of the first time derivative of the step function.

### Yaw Damper Simulation

The yaw damper is designed to reduce the yaw response to disturbances and, in doing so, increases the Dutch roll stability. The yaw damper system is best defined as a electromechanical and composed of a rate gyro which provides an output signal proportional to yaw rate. The signal from the rate gyro is applied to a bandpass filter which removes the low frequency components resulting from steady state turns and the higher frequency components associated with the structural vibrations. After filtering, the

signal is amplified and applied to a servo-motor which results in a hydraulically actuated rudder deflection to oppose the yawing motion.

The method of simulating the yaw damper is illustrated by the simplified block diagram below:



where:

$\dot{\psi}$  = yaw rate, deg/sec.

$e_o$  = input to summation point from filter.

$\delta_{sv}$  = servo output-drum rotation, deg.

$\delta_r$  = rudder rotation, deg.

The transfer function of the servo amplifier and motor combination is approximated by

$$\frac{1}{0.01s^2 + .14s + 1}$$

The response time of the servo is assumed to be negligibly small and the expression for  $e_o$  can be expressed by the following equation.

$$e_o = \frac{.4s}{(.143s + 1)(1.72s + 1)} \dot{\psi} + (.026 + .00208s) \delta_{sv} = 0$$

$$\delta_r = - \frac{.217}{(.1s + 1)} \delta_{sv}$$

$$\delta_r = \frac{3.3 \dot{\psi} s}{(.143s + 1)(1.72s + 1)(.1s + 1)(.08s + 1)} = \dot{\psi} T(s)$$

where

$T(s)$  = yaw damper transfer function

#### Solution of Equations of Motion

The input format for the digital computer program requires that coefficient matrices be formed as indicated.

$$[M_1] \ddot{q}_j + [M_2] \dot{q}_j + [M_3] \ddot{q}_j + [M_4] * q_j + [M_5] * \dot{q}_j = [C_3] * a_g$$

where:

- $[M_1]$  = generalized stiffness matrix.
- $[M_2]$  = non-circulatory response aerodynamic damping matrix.
- $[M_3]$  = generalized inertia matrix.
- $[M_4]$  = circulatory response aerodynamic stiffness matrix.
- $[M_5]$  = circulatory response aerodynamic damping matrix.
- $[C_3]$  = generalized excitation aerodynamic matrix.
- $a_g$  = instantaneous gust angle.
- $*$  = indicates the application of Duhamel's integral to include Wagner or Küssner effects.

The generalized force coefficients associated with rudder deflection due to the yaw damper are formed into a set of matrices defined as  $[S_1 T(s)]$  in the digital computation operation format. The coefficient matrices



for the equations of motion are then modified from the above form to include the yaw damper effects as shown by the following expression:

$$\begin{bmatrix} \tilde{M}_i \end{bmatrix} = \begin{bmatrix} M_i + S_i T(s) \end{bmatrix} \quad i = 1 \text{ through } 5$$

where

$\begin{bmatrix} \tilde{M}_i \end{bmatrix}$  = the new coefficient matrices of  $q_j$ ,  $\dot{q}_j$  and  $\ddot{q}_j$

$\begin{bmatrix} M_i \end{bmatrix}$  = the original coefficient matrices of  $q_j$ ,  $\dot{q}_j$  and  $\ddot{q}_j$

The digital program used for the lateral solution solves for the responses by using the Laplace transformed equations of motion with the Laplace transform variable set equal to  $i\omega$ . The solution then proceeds as follows:

$$\begin{bmatrix} q_j \end{bmatrix} = \left[ \begin{bmatrix} \tilde{M}_1 \end{bmatrix} + i\omega \begin{bmatrix} \tilde{M}_2 \end{bmatrix} - \omega^2 \begin{bmatrix} \tilde{M}_3 \end{bmatrix} + \begin{bmatrix} \tilde{M}_4 \end{bmatrix} * g + i\omega \begin{bmatrix} \tilde{M}_5 \end{bmatrix} * g \right]^{-1} \begin{bmatrix} C_3 * f \end{bmatrix} a_g$$

$g$  = Laplace transform of 1st time derivative of Wagner

$f$  = Laplace transform of 1st time derivative of Küssner

This procedure yields a set of complex generalized responses for the frequency under consideration. The complex generalized responses are then used to compute the load responses. A set of representation solutions for lateral Conditions 10 and 10YD are given in Fig. 28 of the Analyses Section.

## APPENDIX B

### STATISTICAL ANALYSIS FOR COMBINED RANDOM STRESSES

|                                                  | <u>Page No.</u> |
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| Flight Profile Analysis Stress Relationships     | B-10            |
| Crossings of an Arbitrary Strength Envelope      | B-12            |
| Combined Stresses for Vertical and Lateral Gusts | B-25            |

## STATISTICAL ANALYSIS FOR COMBINED RANDOM STRESSES

### Design Envelope Analysis Stress Relationships

The cumulative probability function,  $P(MS \leq 0)$ , is derived from the strength envelope for the structural element in question, the Gaussian joint probability density distribution for the incremental axial and shear stresses on the structural element, and the one-factor level flight stresses. Consider the diagram in Fig. B1 where the joint probability density function for axial and shear stress is shown in relation to the strength envelope defined by the appropriate interaction curves. The probability,  $P(MS > 0, \sigma_w)$ , that the combined axial and shear stresses will not exceed the limit strength for a given root-mean-square gust intensity is equal to the volume of the probability function within the region, R, bounded by the appropriate limit strength envelope.

$$P(MS > 0) = \iint_R p(f, \xi) u f d\xi \quad (B1)$$

Of course, the probability that the margin will be less than zero, that is, that the margin will be negative is,

$$P(MS \leq 0, \sigma_w) = 1 - P(MS > 0, \sigma_w) \quad (B2)$$

The probability function,  $P(MS \leq 0, \sigma_w)$ , can be obtained by several integrations for various  $\sigma_w$  and plotted as illustrated in Fig. B2.

The joint Gaussian probability density function illustrated in Fig. B1 can be expressed as follows:

$$p(f, \xi) = \frac{1}{2\pi\sigma_f\sigma_\xi\sqrt{1-\rho^2}} e^{-G/2} \quad (B3a)$$

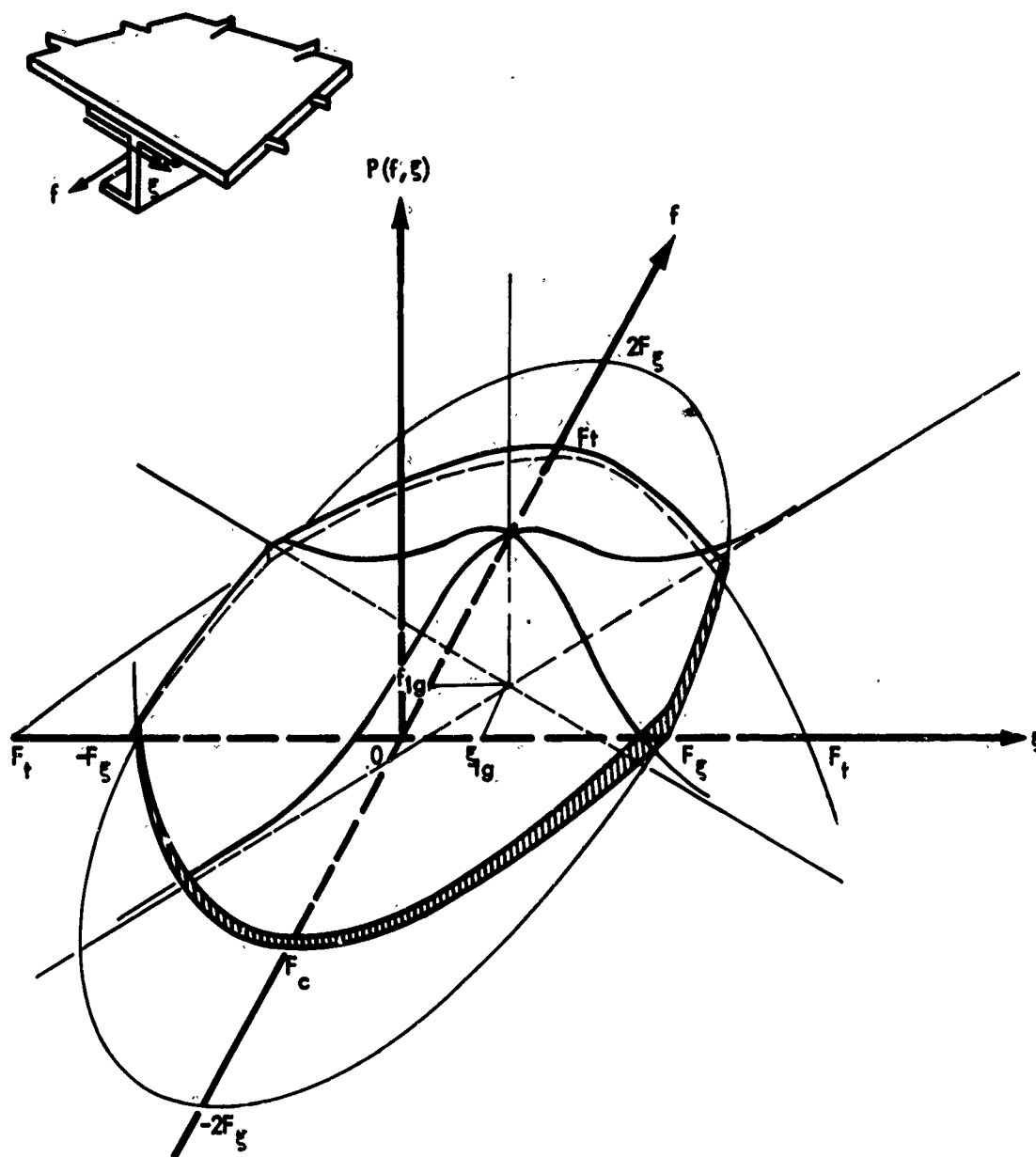


FIGURE B1. JOINT GAUSSIAN PROBABILITY DENSITY FUNCTION

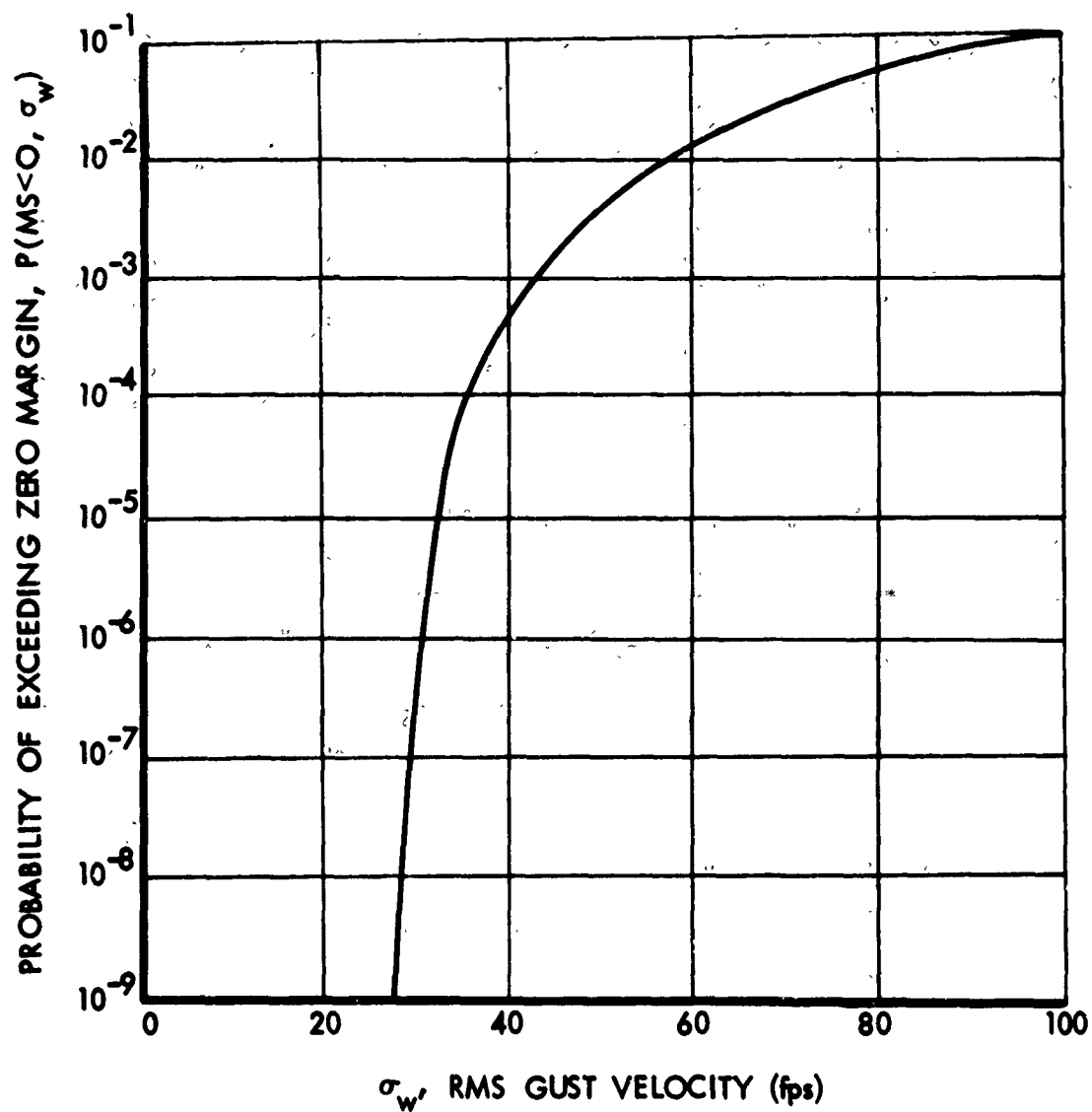


FIGURE B2. PROBABILITY OF EXCEEDING LIMIT DESIGN STRENGTH FOR VARIOUS RMS GUST VELOCITIES

where

$$G = \frac{1}{(1-\rho^2)} \left[ \frac{(\bar{f}-\bar{f})^2}{\sigma_f^2} - \frac{2\rho(\bar{f}-\bar{f})(\bar{\xi}-\bar{\xi})}{\sigma_f\sigma_\xi} + \frac{(\bar{\xi}-\bar{\xi})^2}{\sigma_\xi^2} \right] \quad (B3B)$$

The parameter,  $\rho$ , is the correlation coefficient expressing the statistical correlation between the axial and shear stresses. It can be defined from the cross-power spectrum between the axial and shear stresses as follows:

$$\rho \sigma_f \sigma_\xi = \int_0^\infty \phi_{f\xi}(\omega) d\omega = \text{ave} \{ f(t) \xi(t) \} \quad (B4)$$

Eq. (B4) is derived as follows: Assume that  $h_f(t)$  and  $h_\xi(t)$  are impulse response functions for the axial and shear stresses. Then, the time histories of axial and shear stresses for an arbitrary gust loading,  $w(t)$ , can be determined by convolution.

$$f(t) = \int_0^\infty h_f(r_1) w(t-r_1) dr_1 \quad (B5a)$$

$$\xi(t-r) = \int_0^\infty h_\xi(r_2) w(t-r-r_2) dr_2 \quad (B5b)$$

By definition the cross-correlation function for the axial and shear stresses is,

$$R_{f\xi}(r) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T f(t) \xi(t-r) dt. \quad (B6a)$$

$$R_{f\xi}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \left[ \int_0^\infty h_f(\tau_1) w(t-\tau_1) d\tau_1 \right] \left[ \int_0^\infty h_\xi(\tau_2) w(t-\tau-\tau_2) d\tau_2 \right] \quad (B6b)$$

If we assume that the gust loading has been acting prior to time zero, the lower limits on the convolution integrals can be extended to minus infinity. Also, the order of integration can be changed.

$$R_{f\xi}(\tau) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_f(\tau_1) h_\xi(\tau_2) \left[ \lim_{T \rightarrow \infty} \int_{-T}^T w(t-\tau_1) w(t-\tau-\tau_2) dt \right] d\tau_1 d\tau_2 \quad (B7a)$$

$$R_{f\xi}(\tau) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_f(\tau_1) h_\xi(\tau_2) R_w(\tau-\tau_1+\tau_2) d\tau_1 d\tau_2 \quad (B7b)$$

The cross-power spectral density function is,

$$\phi_{f\xi}(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} R_{f\xi}(\tau) e^{-i\omega\tau} d\tau \quad (B8a)$$

$$\phi_{f\xi}(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_f(\tau_1) h_\xi(\tau_2) \left[ \int_{-\infty}^{\infty} R_w(\tau-\tau_1+\tau_2) e^{-i\omega\tau} d\tau \right] d\tau_1 d\tau_2 \quad (B8b)$$

If we set  $\tau-\tau_1+\tau_2 = \tau_3$  and rewrite the interior integral we obtain,

$$\phi_{f\xi}(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_f(\tau_1) h_\xi(\tau_2) \left[ \int_{-\infty}^{\infty} R_w(\tau_3) e^{-i\omega(\tau_3+\tau_1-\tau_2)} d\tau_3 \right] d\tau_1 d\tau_2 \quad (B8c)$$

Rearranging again, we obtain

$$\phi_{f\xi}(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} h_f(r_1) e^{-i\omega r_1} dr_1 \int_{-\infty}^{\infty} h_{\xi}(r_2) e^{-i\omega r_2} dr_2 \int_{-\infty}^{\infty} R_w(r_3) e^{-i\omega r_3} dr_3 \quad (B8d)$$

However, we note that

$$\phi_w(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} R_w(r_3) e^{-i\omega r_3} dr_3 = \frac{2}{\pi} \int_0^{\infty} R_w(r_3) \cos \omega r_3 dr_3 \quad (B9a)$$

$$H_f(\omega) = \int_{-\infty}^{\infty} h_f(r_1) e^{-i\omega r_1} dr_1 \quad (B9b)$$

$$H_{\xi}^*(\omega) = \int_{-\infty}^{\infty} h_{\xi}(r_3) e^{-i\omega r_3} dr_3 \quad (B9c)$$

where,

- $\phi_w(\omega)$  gust power spectral density function
- $H_f(\omega)$  complex frequency response function for axial stress in the structural element
- $H_{\xi}^*(\omega)$  complex conjugate frequency response function for shear stress in the element.

Therefore,

$$\phi_{f\xi}(\omega) = \phi_w(\omega) H_f(\omega) H_{\xi}^*(\omega) \quad (B10)$$



Obviously, the cross-power spectral density function is complex, that is

$$\phi_{f\xi}(\omega) = C_{f\xi}(\omega) + iq_{f\xi}(\omega) \quad (B11)$$

where,

$C_{f\xi}(\omega)$  real part, cospectrum

$q_{f\xi}(\omega)$  imaginary part, quadrature spectrum

Also we note that,

$$C_{f\xi}(\omega) = C_{\xi f}(\omega) = C_{f\xi}(-\omega) \quad (B12a)$$

$$q_{f\xi}(\omega) = -q_{\xi f}(\omega) = -q_{f\xi}(-\omega) \quad (B12b)$$

Therefore,

$$\text{ave}\{f(t)\xi(t)\} = \rho\sigma_f\sigma_\xi = \frac{1}{2} \int_{-\infty}^{\infty} \phi_{f\xi}(\omega) d\omega = \int_0^{\infty} C_{f\xi}(\omega) d\omega \quad (B4)$$

and

$$\rho = \frac{\frac{1}{2} \int_{-\infty}^{\infty} \phi_w(\omega) H_f(\omega) H_\xi^*(\omega) d\omega}{\left[ \int_0^{\infty} \phi_w(\omega) |H_f(\omega)|^2 d\omega \right]^{1/2} \left[ \int_0^{\infty} \phi_w(\omega) |H_\xi(\omega)|^2 d\omega \right]^{1/2}} \quad (B13)$$

where,

$$\rho\sigma_f\sigma_\xi = \frac{1}{2} \int_{-\infty}^{\infty} \phi_w(\omega) H_f(\omega) H_\xi^*(\omega) d\omega \quad (B14a)$$

$$\sigma_f = \left[ \int_0^\infty \phi_w(\omega) |H_f(\omega)|^2 d\omega \right]^{1/2} \quad (B14b)$$

$$\sigma_\xi = \left[ \int_0^\infty \phi_w(\omega) |H_\xi(\omega)|^2 d\omega \right]^{1/2} \quad (B14c)$$

It will be noted that the correlation coefficient,  $\rho$ , can vary from minus one to plus one.

The strength envelope can be obtained from the expressions for the margin of safety

$$\text{M. S. SHEAR} = \frac{F_\xi}{\left[ \left( \frac{f}{2} \right)^2 + \xi^2 \right]^{1/2}} - 1 \quad (B15)$$

$$\text{M. S. TENSION} = \frac{F_t}{\frac{f}{2} + \left[ \left( \frac{f}{2} \right)^2 + (\xi)^2 \right]^{1/2}} - 1 \quad (B16)$$

$$\text{M. S. COMPRESSION} = \frac{2}{\frac{f}{F_c} + \left[ \left( \frac{f}{F_c} \right)^2 + \left( \frac{\xi}{F_\xi} \right)^2 \right]^{1/2}} - 1 \quad (B17)$$

where,

|         |                          |
|---------|--------------------------|
| $F_\xi$ | Allowable in shear       |
| $F_t$   | Allowable in tension     |
| $F_c$   | Allowable in compression |
| $f$     | Applied normal stress    |

$\xi$  Applied shear stress

MS Margin of safety

Setting the margin of safety equal to zero and solving for the normal stress in terms of the shearing stress one obtains

$$\text{Shear} \quad f = 2 \left\{ \frac{F_t^2}{\xi^2} - \xi^2 \right\}^{1/2} \quad (\text{B18})$$

$$\text{Tension} \quad f = F_t - \frac{\xi^2}{F_t} \quad (\text{B19})$$

$$\text{Compression} \quad f = F_c \left( 1 - \frac{\xi^2}{F_c^2} \right) \quad (\text{B20})$$

The resulting envelope is shown in Fig. B3.

#### Flight Profile Analysis Stress Relationships

The number of times per hour that zero or negative strength margin will occur on a structural element for a given flight condition can be expressed as follows:

$$\bar{G}(\text{MS} \leq 0) = \frac{3600}{2} \int_0^{\infty} N_c(\sigma_w) \hat{f}(\sigma_w) d\sigma_w \quad (\text{B21})$$

where,

$\hat{f}(\sigma_w)$  the probability density distribution of rms gust velocity for the appropriate altitude is given by Eq. ( 2 ), and is repeated below

$$\hat{f}(\sigma_w) = \frac{P_1}{b_1} \sqrt{\frac{2}{\pi}} e^{-\sigma_w^2/2b_1^2} + \frac{P_2}{b_2} \sqrt{\frac{2}{\pi}} e^{-\sigma_w^2/2b_2^2} \quad (\text{B22})$$

The constants  $P_1$ ,  $P_2$ ,  $b_1$ , and  $b_2$  are those given in Figs. 5 and 6.

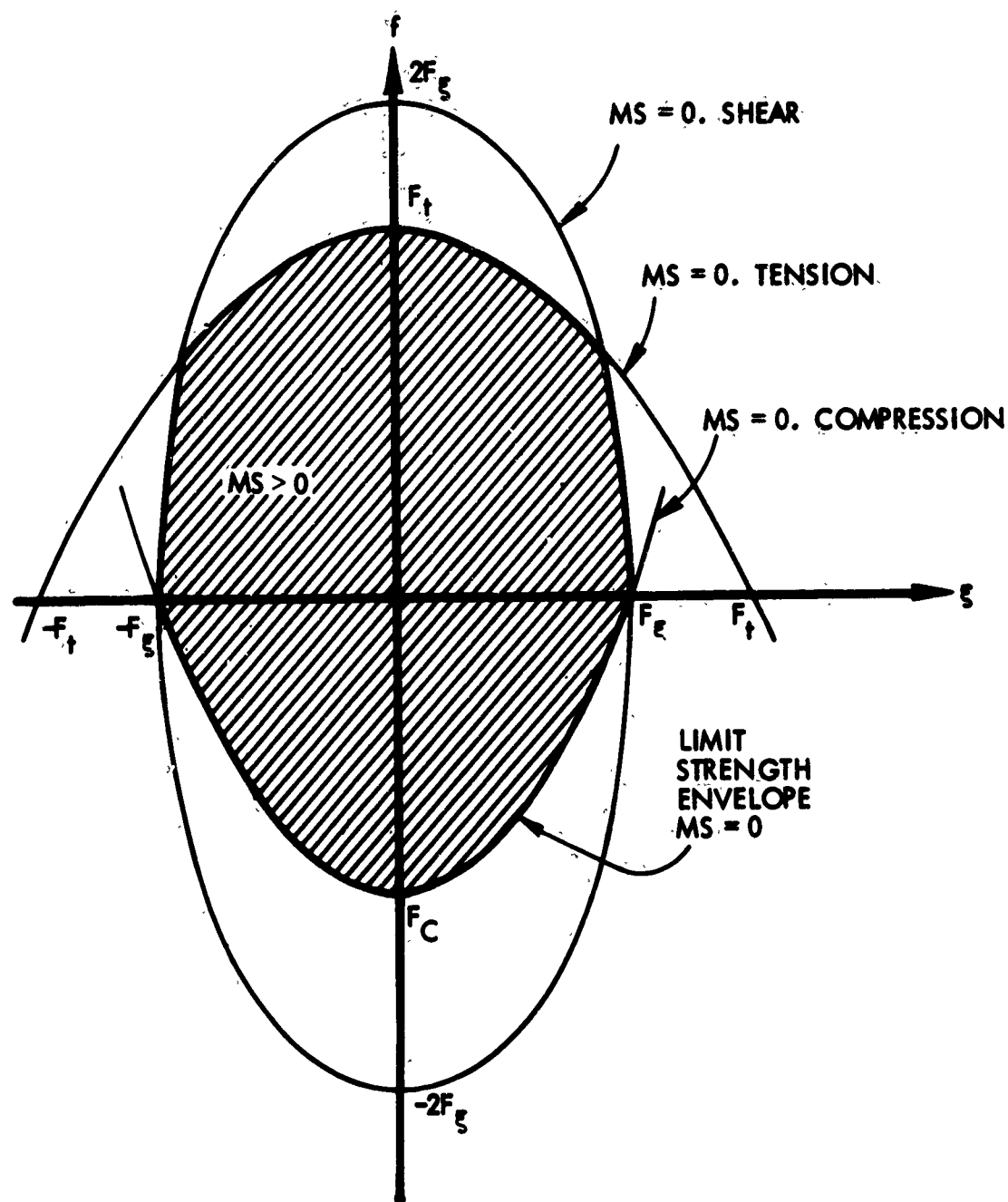


FIGURE B3. LIMIT STRENGTH ENVELOPE

$N_c(\sigma_w)$  Number of crossings of the strength envelope per second for two correlated random stress time histories. The derivation of  $N_c(\sigma_w)$  is given in the following discussion.

#### Crossings of an Arbitrary Strength Envelope

Consider a probability density function

$$p(x, a, y, \beta) dx da dy d\beta = \text{Prob} [x < \xi < x+dx, a < \dot{\xi} < a+da, y < f < y+dy, \beta < \dot{f} < \beta+d\beta]$$

where,

$f$  axial stress, psi

$\beta = \dot{f}$  time rate of change of axial stress, psi per sec.

$\xi$  shear stress, psi

$a = \dot{\xi}$  time rate of change of shear stress, psi per sec.

For a given period of time, the above expression represents the fraction of time per unit time that the stress vector  $\bar{z}(t) = \bar{x}(t)i + \bar{y}(t)j$  spends in the interval  $(x, x+dx; y, y+dy)$  with velocities in the intervals  $(a, a+da; \beta, \beta+d\beta)$ .

The expected number of times per unit time that the stress vector,  $\bar{z}(t)$ , passes through the interaction boundary interval  $(z_C(x, y), z_C(x, y+d\eta))$  is equal to the time spent in the interval divided by the time required to cross the interval.

The time required to cross the interval,  $d\eta$ , is equal to  $d\eta$  divided by the velocity component of  $\bar{z}$  normal to  $C$ , the interaction boundary curve indicated in Fig. B4.

A unit vector normal to  $C$  is,

$$\bar{N} = \frac{\text{grad } C}{|\text{grad } C|} \quad (B24)$$

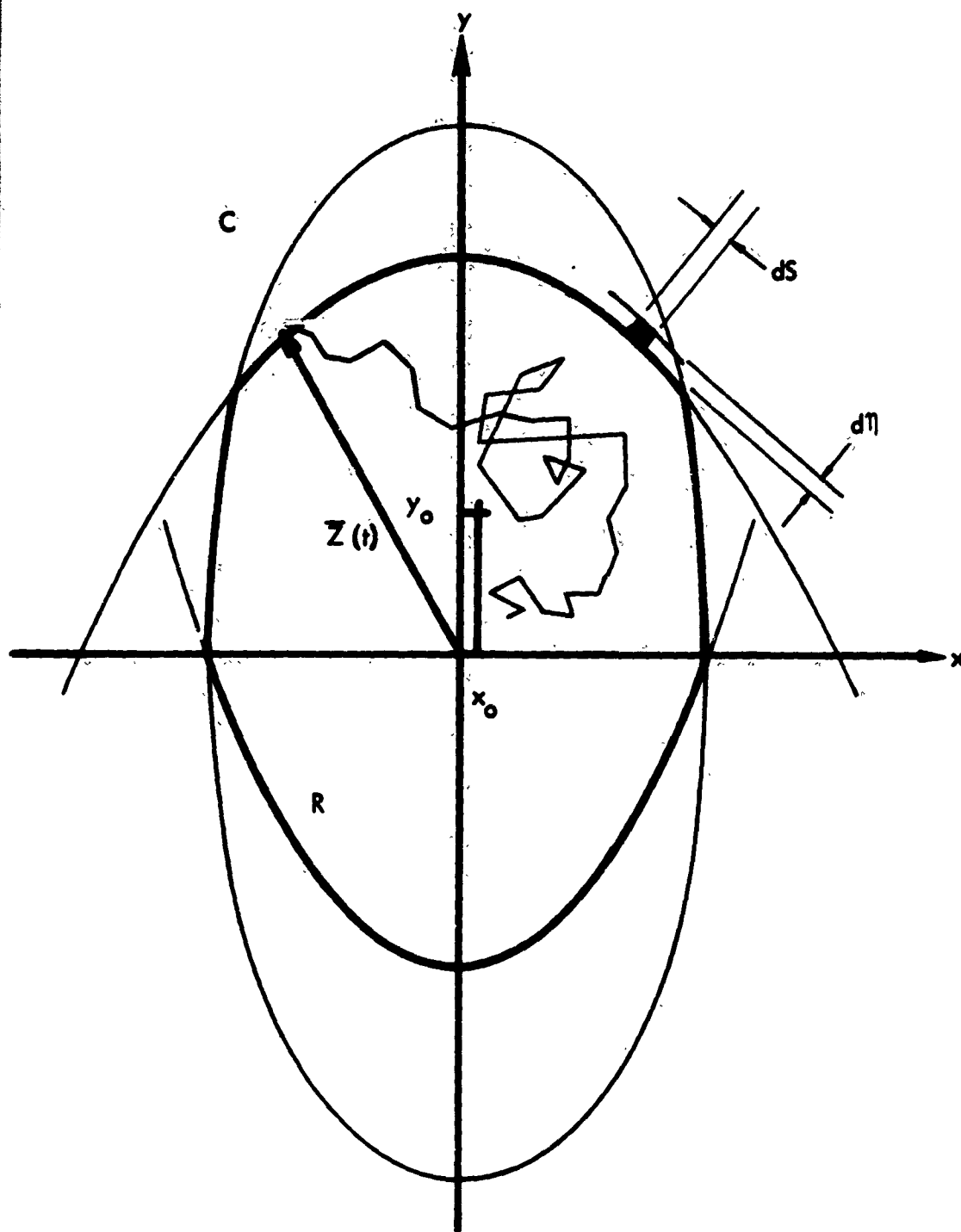


FIGURE B4. COMBINED STRESS VECTOR

If  $C$  is a function of  $x$  and  $y$ , such as

$$y = F_t - \frac{x^2}{F_t}$$

where this function represents an interaction curve for shear and tension,

$$C = y - F_t + \frac{x^2}{F_t} = 0$$

The gradient of  $C$ , denoted,  $\text{grad } C$ , is

$$\frac{\partial C}{\partial x}i + \frac{\partial C}{\partial y}j = \frac{2x}{F_t}i + j$$

The length of the gradient vector is,

$$\sqrt{\left(\frac{\partial C}{\partial x}\right)^2 + \left(\frac{\partial C}{\partial y}\right)^2} = \sqrt{\frac{4x^2}{F_t^2} - 1} = \frac{1}{F_t}\sqrt{4x^2 + F_t^2}$$

Therefore, the unit normal vector on  $C$  is

$$\bar{N} = \frac{2x}{\sqrt{4x^2 + F_t^2}}i + \frac{F_t}{\sqrt{4x^2 + F_t^2}}j \quad (\text{B25})$$

The velocity vector,  $\dot{\bar{z}}$ , is

$$\dot{\bar{z}}(t) = \alpha(t)i + \beta(t)j$$

Then, the rate at which the interval  $d\eta$  is traversed is equal to the dot product of the unit normal vector with the velocity vector.

$$\frac{\text{grad } C}{|\text{grad } C|} \cdot \dot{\bar{z}}(t) = \frac{2ax}{\sqrt{4x^2 + F_t^2}} + \frac{\beta F_t}{\sqrt{4x^2 + F_t^2}}$$

If the time required to cross the interval  $d\eta$  is  $r$ , then,

$$r = \frac{d\eta}{\left| \frac{\text{grad } C}{|\text{grad } C|} \cdot \dot{\bar{z}} \right|} \quad (r > 0) \quad (\text{B26})$$

The expected number of times per unit time that the curve  $C$  is crossed by  $\bar{z}$  with velocities  $\alpha$  and  $\beta$  is equal to the time spent in the interval  $d\eta$  divided by the time required to cross the interval.

$$N_{C\alpha\beta} = \int_C \frac{[P(x, \alpha, y, \beta) d\alpha d\beta] d\eta}{\left| \frac{\text{grad } C}{|\text{grad } C|} \cdot \dot{\bar{z}} \right|} ds \quad (\text{B27})$$

The total number of passages both into the interval  $d\eta$  from the region  $R$  and into the interval toward the region  $R$  is obtained by integrating for all possible velocities  $\alpha$  and  $\beta$ . Therefore, the total number of passages,  $N_C$  is,

$$N_C = \int_{\beta=-\infty}^{\infty} \int_{\alpha=-\infty}^{\infty} \left\{ \int_C [P(x, \alpha, y, \beta)] \left| \frac{\text{grad } C}{|\text{grad } C|} \cdot \dot{\bar{z}} \right| ds \right\} d\alpha d\beta \quad (\text{B28})$$

Now, if the process is Gaussian, the probability density can be written as follows:



$$P(x_1, x_2, x_3, x_4, \dots, x_N) = [2\pi]^{-N/2} |M|^{-1/2} \exp \left\{ \frac{-1}{2|M|} \sum_{i=1}^N \sum_{j=1}^N M_{ij} x_i x_j \right\}, \quad (B29)$$

where  $|M|$  is the determinate of the time averages of the products and cross products of  $x_1, x_2, x_3, \dots, x_N$ , and  $M_{ij}$  is the co-factor of the  $ij$  element of  $|M|$ .

If we let

$$\begin{aligned} x_1 &= x(t) \\ x_2 &= a(t) = \dot{x}(t) \\ x_3 &= y(t) \\ x_4 &= \beta(t) = \dot{y}(t) \end{aligned}$$

then  $|M|$  can be expressed as,

$$|M| = \left| \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \begin{bmatrix} x(t) \\ a(t) \\ y(t) \\ \beta(t) \end{bmatrix} \begin{bmatrix} x(t) & a(t) & y(t) & \beta(t) \end{bmatrix} dt \right| \quad (B30a)$$

or

$$|M| = \left| \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \begin{bmatrix} x^2 & xa & xy & x\beta \\ ax & a^2 & ay & a\beta \\ yx & ya & y^2 & y\beta \\ \beta x & \beta a & \beta y & \beta^2 \end{bmatrix} dt \right| \quad (B30b)$$

The elements of  $|M|$  are determined by carrying out the integration over-time to obtain the following for the  $(i,i)$  elements.

$$\begin{aligned}
\bar{x}^2 &= \sigma_x^2 = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x^2(t) dt = \int_0^\infty \phi_x(\omega) d\omega \\
\bar{a}^2 &= \sigma_a^2 = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T a^2(t) dt = \int_0^\infty \omega^2 \phi_x(\omega) d\omega \\
\bar{y}^2 &= \sigma_y^2 = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T y^2(t) dt = \int_0^\infty \phi_y(\omega) d\omega \\
\bar{\beta}^2 &= \sigma_\beta^2 = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \beta^2(t) dt = \int_0^\infty \omega^2 \phi_y(\omega) d\omega
\end{aligned} \tag{B30c}$$

For the (1,2) and (2,1) elements we obtain,

$$\lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t) \dot{x}(t) dt = 0$$

This is determined by integrating by parts and by taking the limit,

$$\lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t) \dot{x}(t) dt = \lim_{T \rightarrow \infty} \frac{1}{2T} \left\{ \left[ x(t) \dot{x}(t) \right]_{-T}^T - \int_{-T}^T x(t) \ddot{x}(t) dt \right\} . \tag{B31}$$

Then,

$$\lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t) \dot{x}(t) dt = \lim_{T \rightarrow \infty} \frac{1}{4T} [x(T) - x(-T)] = 0$$

This integral is identically equal to zero, since the respective values of  $x(T)$  and  $x(-T)$  are always finite and they are divided by  $T$  which is arbitrarily large.

Therefore, the (1,2) and (2,1) elements of  $|M|$  are zero.

The (1,3) and (3,1) elements are by definition of the cross correlation between  $x(t)$  and  $y(t)$  and are

$$\overline{xy} = \rho \sigma_x \sigma_y = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t)y(t)dt = \frac{1}{2} \int_{-\infty}^{\infty} \phi_{xy}(\omega) d\omega \quad (B32)$$

where  $\rho$  is the correlation coefficient which varies in the interval (1,-1).

All other elements are more obscure will be assumed equal to zero.

Therefore,

$$|M| = \begin{vmatrix} \sigma_x^2 & 0 & \rho \sigma_x \sigma_y & 0 \\ 0 & \sigma_a^2 & 0 & 0 \\ \rho \sigma_x \sigma_y & 0 & \sigma_y^2 & 0 \\ 0 & 0 & 0 & \sigma_\beta^2 \end{vmatrix} \quad (B33)$$

The frequency density is now expressed as follows:

$$P(x,a,y,\beta) = \frac{1}{(2\pi)^2} \frac{1}{\sigma_x \sigma_a \sigma_y \sigma_\beta (1-\rho^2)^{1/2}} \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{x^2}{\sigma_x^2} - \frac{2\rho xy}{\sigma_x \sigma_y} + \frac{y^2}{\sigma_y^2} \right] \right\} \quad (B34)$$

$$\exp \left\{ -\frac{1}{2} \left[ \frac{a^2}{\sigma_a^2} + \frac{\beta^2}{\sigma_\beta^2} \right] \right\}$$

If we assume that  $x$  and  $y$  shown in Eq. (B34) are incremental or time variant values varying from the mean or one-factor flight values, then,  $x$  is replaced by  $(x-x_0)$  and  $y$  by  $(y-y_0)$ .

$$p(x, a, y, \beta) = \frac{1}{(2\pi)^2} \frac{1}{\sigma_x \sigma_a \sigma_y \sigma_\beta (1-\rho^2)^{1/2}} \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{(x-x_0)^2}{\sigma_x^2} \right. \right. \\ \left. \left. - 2\rho \frac{(x-x_0)(y-y_0)}{\sigma_x \sigma_y} + \frac{(y-y_0)^2}{\sigma_y^2} \right] \right\} \exp \left\{ -\frac{1}{2} \left[ \frac{a^2}{\sigma_a^2} + \frac{\beta^2}{\sigma_\beta^2} \right] \right\} \quad (B35)$$

Substituting Eq. (B35) into Eq. (B27), we obtain

$$N_{C_{a\beta}} = \frac{1}{(2\pi)^2} \frac{1}{\sigma_x \sigma_a \sigma_y \sigma_\beta (1-\rho^2)^{1/2}} \exp \left\{ -\frac{1}{2} \left[ \frac{a^2}{\sigma_a^2} + \frac{\beta^2}{\sigma_\beta^2} \right] \right\} \int_C \left| \frac{\text{grad } C}{|\text{grad } C|} \cdot \frac{\dot{z}}{z} \right| \\ \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{(x-x_0)^2}{\sigma_x^2} - 2\rho \frac{(x-x_0)(y-y_0)}{\sigma_x \sigma_y} + \frac{(y-y_0)^2}{\sigma_y^2} \right] \right\} dS da d\beta \quad (B36)$$

The number of crossings per unit time is obtained from Eqs. (B28) and (B35).

$$N_C = \frac{1}{(2\pi)^2} \frac{1}{\sigma_x \sigma_a \sigma_y \sigma_\beta (1-\rho^2)^{1/2}} \int_{a=-\infty}^{\infty} \int_{\beta=-\infty}^{\infty} \int_C \left| \frac{\text{grad } C}{|\text{grad } C|} \cdot \frac{\dot{z}}{z} \right| \\ \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{(x-x_0)^2}{\sigma_x^2} - 2\rho \frac{(x-x_0)(y-y_0)}{\sigma_x \sigma_y} + \frac{(y-y_0)^2}{\sigma_y^2} \right] \right\} \exp \left\{ -\frac{1}{2} \left[ \frac{a^2}{\sigma_a^2} + \frac{\beta^2}{\sigma_\beta^2} \right] \right\} dS da d\beta \quad (B37)$$

If we assume zero mean values for  $x(t)$  and  $y(t)$ , we can easily obtain the familiar expression for the number of times per unit time that  $z(t) = x(t)i + y(t)j$  crosses a constant level,  $y = a$ .

The general equation for the number of crossings per unit time is obtained in Eq. (B37). If we assume that

$$C = y - a; \quad \frac{\partial C}{\partial x} = 0; \quad \frac{\partial C}{\partial y} = 1$$

and the grad  $C = 0i + 1j$ . Then,  $|\text{grad } C| = 1$ . The velocity vector component of  $\alpha i + \beta j$  normal to  $C$  is,

$$\beta = (0i + 1j) \cdot (\alpha i + \beta j)$$

Then,

$$\left| \frac{\text{grad } C}{|\text{grad } C|} \cdot \dot{z} \right| = |\beta|$$

If Eq. (B37) is rewritten for this example, we obtain,

$$N_C = \frac{1}{2\pi} \frac{1}{\sigma_a \sigma_\beta} \int_{a=-\infty}^{\infty} \int_{\beta=-\infty}^{\infty} |\beta| \exp \left\{ -\frac{1}{2} \left[ \frac{a^2}{\sigma_a^2} + \frac{\beta^2}{\sigma_\beta^2} \right] \right\} da d\beta \quad (\text{B38})$$

$$\int_{x=-\infty}^{\infty} \frac{1}{2\pi} \frac{1}{\sigma_x \sigma_y (1-\rho^2)^{1/2}} \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{x^2}{\sigma_x^2} - \frac{2\rho xy}{\sigma_x \sigma_y} + \frac{y^2}{\sigma_y^2} \right] \right\} dx$$

We note that integral over  $x$  is identically equal to

$$\int_{x=-\infty}^{\infty} = \frac{1}{\sqrt{2\pi} \sigma_y} e^{-y^2/2\sigma_y^2} \quad (\text{B39a})$$

and the double integral can be rewritten in simpler form after the following integrations are made:

$$\int_{a=-\infty}^{\infty} e^{-a^2/2\sigma_a^2} da = \sqrt{2\pi} \sigma_a \quad \text{since,} \quad (\text{B39b})$$

$$\frac{1}{\sqrt{2\pi} \sigma_a} \int_{a=-\infty}^{\infty} e^{-a^2/2\sigma_a^2} da = 1 \quad (\text{B39c})$$

The integral over  $\beta$  can be written as,

$$\int_{\beta=-\infty}^{\infty} |\beta| e^{-\beta^2/2\sigma_\beta^2} d\beta = 2 \int_0^{\infty} \beta e^{-\beta^2/2\sigma_\beta^2} d\beta = 2\sigma_\beta^2 \quad (\text{B39d})$$

The double integral over  $a$  and  $\beta$  is equal to

$$\int_a \int_\beta = 2\sqrt{2\pi} \sigma_a \sigma_\beta^2 \quad (\text{B39e})$$

Substituting Eqs. (B39a) and (B39b) into Eq. (B38) gives,

$$N_C = \frac{1}{2\pi} \frac{1}{\sigma_a \sigma_\beta} (2\sqrt{2\pi} \sigma_a \sigma_\beta^2) \frac{1}{\sqrt{2\pi} \sigma_y} e^{-y^2/2\sigma_y^2} \quad (\text{B39f})$$

Reducing Eq. (B39f) gives,

$$N_C = \frac{1}{\pi} \frac{\sigma_\beta}{\sigma_y} e^{-y^2/2\sigma_y^2} \quad (\text{B40})$$

This is the well known expression for the total number of crossings of a level  $y = a$ , where  $a$  is arbitrary in magnitude and in sign. (14)

The preceding derivation treated a continuous envelope  $C$ ; however, the algebra is simpler if the envelope is defined by a series of straight line segments. In the following development, an expression for the value of  $N_C$  is determined for one of these line segments. Through a cycling process the  $N_C$  for any envelope can be determined.

Consider the number of crossings per unit time of an arbitrary straight line segment from  $(x_1, y_1)$  to  $(x_2, y_2)$ . The equation of the line through the point is,

$$y = \left( \frac{y_1 - y_2}{x_1 - x_2} \right) (x - x_1) + y_1 \quad (B41a)$$

or

$$y = m(x - x_1) + y_1$$

where  $m$  is the slope.

Therefore,

$$C = y - m(x - x_1) - y_1 = 0$$

$$\frac{\partial C}{\partial x} = -m; \quad \frac{\partial C}{\partial y} = 1; \quad \text{grad } C = -mi + j \quad (B42)$$

The absolute value of the grad  $C$  is,

$$|\text{grad } C| = |\sqrt{m^2 + 1}|$$

Then,

$$\left| \frac{\text{grad } C}{|\text{grad } C|} \cdot \frac{\dot{z}}{z} \right| = \left| \frac{(-mi + j) \cdot (ai + \beta j)}{\sqrt{m^2 + 1}} \right| \quad (\text{B43})$$

$$\bar{N} = \left| \frac{-m a + \beta}{\sqrt{m^2 + 1}} \right|$$

Assuming  $x_0 = y_0 = 0$ , we can rewrite Eq. (B37) as,

$$N_C = \frac{1}{(2\pi)^2} \frac{1}{\sigma_x \sigma_a \sigma_y \sigma_\beta (1-\rho^2)^{1/2}} \int_{a=-\infty}^{\infty} \int_{\beta=-\infty}^{\infty} \int_C \left| \frac{-m a + \beta}{\sqrt{m^2 + 1}} \right| \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{x^2}{\sigma_x^2} - \frac{2\rho xy}{\sigma_x \sigma_y} + \frac{y^2}{\sigma_y^2} \right] \right\} dS \quad (\text{B44})$$

$$\exp \left\{ -\frac{1}{2} \left[ \frac{a^2}{\sigma_a^2} + \frac{\beta^2}{\sigma_\beta^2} \right] \right\} da d\beta$$

Eq. (B44) can be rearranged and applied to the k-th segment of the strength envelope:

$$N_{C_k} = \frac{1}{2\pi} \frac{1}{\sigma_a \sigma_\beta} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left| \frac{-m a + \beta}{\sqrt{m^2 + 1}} \right|^{1/2} \exp \left\{ -\frac{1}{2} \left[ \frac{a^2}{\sigma_a^2} + \frac{\beta^2}{\sigma_\beta^2} \right] \right\} da d\beta \quad (\text{B45})$$

$$\frac{1}{2\pi} \frac{1}{\sigma_x \sigma_y (1-\rho^2)^{1/2}} \int_{x_1, y_1}^{x_2, y_2} \exp \left\{ \frac{-1}{2(1-\rho^2)} \left[ \frac{x^2}{\sigma_x^2} - \frac{2\rho xy}{\sigma_x \sigma_y} + \frac{y^2}{\sigma_y^2} \right] \right\} dS$$

Eq. (B45) shows that  $N_{C_k}$  is the product of a slope-velocity function, which is constant for a given line segment, and a line integral over the joint probability function,  $P(x,y)$ . While it is possible to express



both functions in series form, it has been found to be advantageous to evaluate the slope-velocity term by an infinite series and to evaluate the second function directly.

The suggested method of solution is to numerically evaluate the crossing density,  $dN_{c_k}/dS$ , at a sufficient number of points along the various line segments around the strength envelope.

$$\frac{dN_{c_k}}{dS} = \left\{ \sqrt{\frac{2}{\pi}} \left[ \frac{\sigma_\beta^2}{[m^2 \sigma_a^2 + \sigma_\beta^2]^{1/2}} + \frac{\sigma_a^2}{\sigma_\beta^2} \sum_{n=0}^{\infty} \frac{(-1)^n m^{(2n+2)} (2n)!}{(n!)^2} \left( \frac{\sigma_a}{2\sigma_\beta} \right)^{2n} \right] \right. \\ \left. \left\{ \frac{1}{2\pi} \frac{1}{\sigma_x \sigma_y (1-\rho^2)^{1/2}} \exp \left[ \frac{-1}{2(1-\rho^2)} \left[ \frac{x^2}{\sigma_x^2} - \frac{2\rho xy}{\sigma_x \sigma_y} + \frac{y^2}{\sigma_y^2} \right] \right] \right\} \right\} \quad (B46)$$

The crossings of the k-th segment of the strength envelope can be determined as follows:

$$N_{c_k} = \left\{ \sqrt{\frac{2}{\pi}} \left[ \frac{\sigma_\beta^2}{[m^2 \sigma_a^2 + \sigma_\beta^2]^{1/2}} + \frac{\sigma_a^2}{\sigma_\beta^2} \sum_{n=0}^{\infty} \frac{(-1)^n m^{(2n+2)} (2n)!}{(n!)^2} \left( \frac{\sigma_a}{2\sigma_\beta} \right)^{2n} \right] \right\} \\ \left\{ \int_{c_k} p(x,y) dS_k \right\} \quad (B47)$$

Eq. (B47) can be properly evaluated if the series converges and if the second term, the line integral, is carefully evaluated over each line segment. The convergence of the series in less than 30 terms can be assured if (1) the ratio  $\sigma_a/\sigma_\beta$  is normalized to unity, and if the line segment slopes are restricted to the interval  $(-1,1)$ .

The ratio  $\sigma_a/\sigma_\beta$  can be made equal to unity by stretching the strength envelope and all x-dependent parameters by the ratio  $\sigma_a/\sigma_\beta$ . The stretching, of course, will change the slopes of the line segments.  $N_{c_k}$  can be evaluated directly after transformation for all line segments with slopes in the interval  $(-1,1)$ . Segments with slopes outside the interval  $(-1,1)$  can be handled by exchanging the coordinates in Eq. (B47).

### Combined Stresses for Vertical and Lateral Gusts

Calculations to estimate airplane loads and stresses resulting from flight in continuous atmospheric turbulence are nearly always carried out under the assumption that the vertical and lateral motions of the airplane are not coupled. As a result, two separate analyses are usually conducted; one for the vertical component of the turbulent gust velocity field and a separate analysis for the lateral. However, certain parts of the airplane, particularly the fuselage and empennage, are stressed significantly by the simultaneous action of both the vertical and lateral gust components. It is shown in the following development, that stresses derived separately from vertical and lateral power spectral gust analyses can be combined in a simple manner if the turbulent gust velocity field is isotropic.

Consider two stress components in a structural element in the fuselage. Let  $f_v(t)$  be the axial stress time-history that results from the vertical component of turbulence, and let  $\xi_L(t)$  be the shear stress resulting from the lateral component of turbulence. The cross correlation between these two stress components can be expressed as follows:

$$R_{f_v \xi_L}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T f_v(t) \xi_L(t-\tau) dt \quad (B48)$$

Expressions for the time-histories of  $f_v(t)$  and  $\xi_L(t)$  can be written in terms of the stress impulse response functions  $h_{f_v}(\tau)$  and  $h_{\xi_L}(\tau)$  and the gust time-histories using summation integrals.

$$f_v(t) = \int_{-\infty}^{\infty} h_{f_v}(\tau_1) w(t-\tau_1) d\tau_1 \quad (B49a)$$

$$\xi_L(t-\tau) = \int_{-\infty}^{\infty} h_{\xi_L}(\tau_2) v(t-\tau-\tau_2) d\tau_2 \quad (B49b)$$

Eq. (B48) can now be rewritten as follows:

$$R_{f_v \xi_L}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \left[ \int_{-\infty}^{\infty} h_{f_v}(\tau_1) w(t-\tau_1) d\tau_1 \right] \left[ \int_{-\infty}^{\infty} h_{\xi_L}(\tau_2) v(t-\tau-\tau_2) d\tau_2 \right] dt \quad (B50a)$$

Rearranging the order of integration, we obtain,

$$R_{f_v \xi_L}(\tau) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_{f_v}(\tau_1) h_{\xi_L}(\tau_2) \left[ \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T w(t-\tau_1) v(t-\tau-\tau_2) dt \right] d\tau_1 d\tau_2 \quad (B50b)$$

It will be noted that the term in brackets in Eq. (B50b) is the cross-correlation function for the vertical and lateral gust velocity components.

$$R_{wv}(\tau-\tau_1+\tau_2) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T w(t-\tau_1) v(t-\tau-\tau_2) dt \quad (B51)$$

The cross-power spectral density function for the two stress components is,

$$\phi_{f_v \xi_L}(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} R_{wv}(\tau_3) e^{-i\omega\tau_3} d\tau_3 \quad (B52)$$

where,

$$\tau_3 = \tau - \tau_1 + \tau_2 \quad (B53)$$

After substituting Eqs. (B53) and (B51) into (B50b) and rewriting Eq. (B52), we have,

$$\phi_{f_v \xi_L}(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_{f_v}(r_1) h_{\xi_L}(r_2) \left[ \int_{-\infty}^{\infty} R_{wv}(r_3) e^{-i\omega(r_3+r_1-r_2)} dr_3 \right] dr_1 dr_2 \quad (B54)$$

Rearranging the order of integration in Eq. (B54) gives,

$$\phi_{f_v \xi_L}(\omega) = \frac{1}{\pi} \int_{-\infty}^{\infty} h_{f_v}(r_1) e^{-i\omega r_1} dr_1 \int_{-\infty}^{\infty} h_{\xi_L}(r_2) e^{i\omega r_2} dr_2 \int_{-\infty}^{\infty} R_{wv}(r_3) e^{-i\omega r_3} dr_3 \quad (B55)$$

$$\phi_{f_v \xi_L}(\omega) = H_{f_v}(\omega) H_{\xi_L}^*(\omega) \phi_{wv}(\omega)$$

where,

$H_{f_v}(\omega)$  complex frequency response function for axial stress on the element resulting from the vertical component of atmospheric turbulence

$H_{\xi_L}(\omega)$  complex conjugate frequency response function for shear stress on the element resulting from the lateral component of turbulence.

$\phi_{wv}(\omega)$  cross-power spectral density function for the vertical and lateral gust velocity components.

The integral of the cross-power spectrum in Eq. (B55) gives

$$\rho_{f_v \xi_L} \sigma_{f_v} \sigma_{\xi_L} = \frac{1}{2} \int_{-\infty}^{\infty} H_{f_v}(\omega) H_{\xi_L}^*(\omega) \phi_{wv}(\omega) d\omega \quad (B56)$$

where  $\rho_{f_v \xi_L}$  is the correlation coefficient.

Eq. (B56) provides the same result as the following integral:

$$\rho_{f_v \xi_L} \sigma_{f_v} \sigma_{\xi_L} = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T f_v(t) \xi_L(t) dt \quad (B57)$$

The axial and shear stresses at a point in the airplane structure resulting from the vertical component and the lateral component of atmospheric turbulence are as follows:

$$\begin{aligned} f(t) &= f_v(t) + f_L(t) \\ \xi(t) &= \xi_v(t) + \xi_L(t) \end{aligned} \quad (B58)$$

The matrix of mean squared stresses used to define the joint probability distribution is,

$$\begin{aligned} [M] &= \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \begin{bmatrix} f_v + f_L \\ \xi_v + \xi_L \end{bmatrix} \begin{bmatrix} (f_v + f_L) & (\xi_v + \xi_L) \end{bmatrix} dt \\ [M] &= \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \begin{bmatrix} (f_v + f_L)^2 & (f_v + f_L)(\xi_v + \xi_L) \\ (f_v + f_L)(\xi_v + \xi_L) & (\xi_v + \xi_L)^2 \end{bmatrix} dt \\ [M] &= \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T \begin{bmatrix} (f_v^2 + 2f_v f_L + f_L^2) & (f_v \xi_v + f_v \xi_L + f_L \xi_v + f_L \xi_L) \\ (f_v \xi_v + f_v \xi_L + f_L \xi_v + f_L \xi_L) & (f_v^2 + 2\xi_v \xi_L + \xi_L^2) \end{bmatrix} dt \end{aligned} \quad (B59)$$

If it is assumed that the turbulence is isotropic, the time averaged product of two gust velocities  $w(x_1, t)$  and  $v(x_2, t)$  at two points  $x_1$  and  $x_2$  along the airplane fuselage is,

$$\begin{aligned}
\rho_{w_{x_1} v_{x_2}} \sigma_w \sigma_v &= \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T w(x_1, t) v(x_2, t) dt \\
&= \overline{wv} \quad (B60) \\
&= R_{wv}(|x_1 - x_2|)
\end{aligned}$$

It would be expected that the above space correlation would be sensitive to the absolute value of  $x_1$  minus  $x_2$ . However, in the same manner as von Karman and Howarth<sup>(15)</sup>, it can be shown that this correlation is always identically zero for isotropic turbulence for any  $x_1$  and  $x_2$ .

If we rotate the coordinate axis system about either the y or z-axis by  $180^\circ$ , and denote the transformed velocities  $\tilde{w}$  and  $\tilde{v}$ , respectively, we observe that

$$\overline{wv} = \overline{\tilde{w}\tilde{v}} \quad (B61a)$$

But by the isotropic property,

$$\overline{wv} = \overline{\tilde{w}\tilde{v}} \quad (B61b)$$

Therefore,

$$\overline{wv} \equiv 0 \quad (B61c)$$

Since,

$$\sigma_w \neq 0, \quad \sigma_v \neq 0 \quad (B62a)$$

then,

$$\rho_{wv} = 0 \quad (B62b)$$

Therefore, the vertical and lateral components of isotropic turbulence are not correlated, and the cross power spectral density function for the vertical and lateral components of gust velocity is identically zero for all frequencies. Now, by Eq. (B56) we see that all of the correlation coefficients relating stress components arising separately from the vertical and lateral components of isotropic turbulence are also equal to zero.

The matrix of mean squared stresses used to define the joint probability distribution is obtained by integrating the remaining terms in Eq. (B59).

$$[M] = \begin{bmatrix} \sigma_{f_v}^2 + \sigma_{f_L}^2 & \rho_x \sigma_{f_v} \sigma_{\xi_v} + \rho_L \sigma_{f_L} \sigma_{\xi_L} \\ \rho_v \sigma_{f_v} \sigma_{\xi_v} + \rho_L \sigma_{f_L} \sigma_{\xi_L} & \sigma_{\xi_v}^2 + \sigma_{\xi_L}^2 \end{bmatrix} \quad (B63)$$

Now, the total mean squared stresses from the vertical and lateral analysis results are,

$$\begin{aligned} \sigma_f^2 &= \sigma_{f_v}^2 + \sigma_{f_L}^2 \\ \sigma_{\xi}^2 &= \sigma_{\xi_v}^2 + \sigma_{\xi_L}^2 \end{aligned} \quad (B64)$$

and the correlation coefficient relating the total axial and total shear stresses is,

$$\rho = \frac{\rho_v \sigma_{f_v} \sigma_{\xi_v} + \rho_L \sigma_{f_L} \sigma_{\xi_L}}{\sigma_f \sigma_{\xi}} \quad (B65)$$

The power spectral density function for the total axial stress can be obtained from the total autocorrelation function

$$R_f(r) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T [f_v(t) + f_L(t)] [f_v(t+r) + f_L(t+r)] dt \quad (B66)$$

Then,

$$\phi_f(\omega) = \frac{2}{\pi} \int_0^{\infty} R_f(r) e^{-i\omega r} dr \quad (B67a)$$

$$= \frac{2}{\pi} \int_0^{\infty} \left[ \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T f_v(t) f_v(t+r) dt + \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T f_L(t) f_L(t+r) dt \right] e^{-i\omega r} dr \quad (B67b)$$

$$\phi_f(\omega) = \frac{2}{\pi} \int_0^{\infty} \left[ R_{f_v}(r) + R_{f_L}(r) \right] e^{-i\omega r} dr \quad (B68)$$

The total number of level crossings per second with both positive and negative slope for one stress component can be obtained from Rice's expression (14).

$$N_{O_f} = \frac{1}{\pi} \left[ \frac{\int_0^{\infty} \omega^2 \phi_f(\omega) d\omega}{\int_0^{\infty} \phi_f(\omega) d\omega} \right]^{1/2} \quad (B69)$$

Substituting Eq. (B68) into Eq. (B69), we have

$$N_{O_f} = \frac{1}{\pi} \left[ \frac{\int_0^{\infty} \omega^2 \phi_{f_v}(\omega) d\omega + \int_0^{\infty} \omega^2 \phi_{f_L}(\omega) d\omega}{\int_0^{\infty} \phi_{f_v}(\omega) d\omega + \int_0^{\infty} \phi_{f_L}(\omega) d\omega} \right]^{1/2} \quad (B70)$$



Then,

$$N_{O_f} = \frac{1}{\pi} \left[ \frac{\sigma_{\beta_{f_V}}^2 + \sigma_{\beta_{f_L}}^2}{\sigma_{f_V}^2 + \sigma_{f_L}^2} \right]^{1/2} = \frac{1}{\pi} \left[ \frac{\sigma_{\beta_f}}{\sigma_f} \right] \quad (B71a)$$

$$N_{O_\xi} = \frac{1}{\pi} \left[ \frac{\sigma_{a_{\xi_V}}^2 + \sigma_{a_{\xi_L}}^2}{\sigma_{\xi_V}^2 + \sigma_{\xi_L}^2} \right]^{1/2} = \frac{1}{\pi} \left[ \frac{\sigma_{a_\xi}}{\sigma_\xi} \right] \quad (B71b)$$

The values  $\sigma_\xi$ ,  $\sigma_{a_\xi}$ ,  $\sigma_f$ ,  $\sigma_{a_f}$  and  $\rho$  derived from Eq. (B65), (B71a) and (B71b) can be used in the joint probability statistical analysis described previously.

APPENDIX C  
NUMERICAL RESULTS

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| Flight Profile Approach - Lateral Analyses - Yaw<br>Damper On  | C-54            |
| Design Envelope Approach - Lateral Analyses - Yaw<br>Damper On | C-67            |
| Design Envelope Approach - Lateral Analyses                    | C-73            |
| Parametric Variations - Lateral Analyses                       | C-79            |

## APPENDIX C

### NUMERICAL RESULTS

The wing, body and vertical tail loads resulting from a one foot per second rms gust,  $\bar{A}$ , and corresponding number of crossings per second,  $N_0$ , are tabulated on the following pages. The condition numbers correspond with those shown in Tables 2 through 5 in the Analysis Conditions section.

# CONDITION 1 VERTICAL ANALYSIS

GW 181,600 LB.  
 ALT. 5,000 FT.  
 CG 18.6 PERCENT MAC

SPEED  
 V<sub>4</sub> 290 KT  
 V<sub>6</sub> 269 KT  
 M .45

CG ACCELERATION:  
 X .01642 g  
 N 1.609 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |                         | BEAM SHEAR |        |                         | TORSION                 |        |                         |
|--------------|--------|-------------------------|--------|-------------------------|------------|--------|-------------------------|-------------------------|--------|-------------------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | N <sub>o</sub> PER SEC. | LB.        |        | N <sub>o</sub> PER SEC. | 10 <sup>3</sup> IN. LB. |        | N <sub>o</sub> PER SEC. |
|              |        | X                       | 19     |                         | X          | 19     |                         | X                       | 19     |                         |
| 0            | 0      | 213.6                   | 14,900 | 1.088                   | 586.8      | 48,600 | 1.381                   | 69.28                   | -2,600 | 1.513                   |
| 94.4         | 12     | 183.3                   | 12,000 | .9616                   | 447.4      | 37,200 | 1.701                   | 31.58                   | -1,530 | 2.993                   |
| 157.3        | 20     | 161.0                   | 10,400 | .8986                   | 417.7      | 31,200 | 1.726                   | 30.39                   | -900   | 3.001                   |
| 252.6        | 33     | 123.2                   | 7,500  | .9981                   | 374.1      | 22,300 | 1.685                   | 31.07                   | -550   | 2.769                   |
| 322.5        | 41     | 93.54                   | 5,800  | .9945                   | 379.6      | 26,000 | .9870                   | 17.99                   | -250   | 2.201                   |
| 432.7        | 55     | 52.54                   | 3,150  | 1.201                   | 295.2      | 16,600 | 1.151                   | 17.92                   | -380   | 2.154                   |
| 503.5        | 64     | 34.20                   | 2,150  | 1.319                   | 246.2      | 9,150  | 1.430                   | 18.55                   | -400   | 2.068                   |
| 550.7        | 70     | 21.42                   | 1,500  | 1.352                   | 179.6      | 12,200 | 1.118                   | 2.937                   | -50    | 2.270                   |
| 645.1        | 82     | 6.613                   | 450    | 1.512                   | 95.82      | 6,000  | 1.421                   | 1.686                   | -30    | 2.129                   |
| 715.9        | 91     | 1.450                   | 100    | 1.999                   | 40.10      | 2,700  | 1.476                   | .8031                   | -10    | 2.571                   |

## CONDITION 1

## VERTICAL ANALYSIS

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |                         | SHEAR |         |                         |
|----------------------|-------------------------|---------|-------------------------|-------|---------|-------------------------|
|                      | 10 <sup>3</sup> IN. LB. |         | N <sub>o</sub> PER SEC. | LB.   |         | N <sub>o</sub> PER SEC. |
|                      | X                       | 19      |                         | X     | 19      |                         |
| 300                  | 15.04                   | -740    | 3.907                   | 170.3 | -10,090 | 3.418                   |
| 480                  | 65.00                   | -3,950  | 3.096                   | 374.7 | -25,650 | 2.641                   |
| 620                  | 122.9                   | -8,226  | 2.767                   | 466.3 | -34,900 | 2.232                   |
| 720                  | 170.5                   | -       | 2.581                   | 520.4 | -       | 1.960                   |
| 820                  | 182.7                   | -18,050 | 2.388                   | 568.2 | -53,890 | 1.323                   |
| 1000                 | 132.2                   | -13,160 | 2.762                   | 484.6 | -39,010 | 1.610                   |
| 1160                 | 79.39                   | -7,624  | 3.197                   | 321.6 | -28,970 | 2.290                   |
| 1320                 | 45.11                   | -3,802  | 3.259                   | 190.3 | -23,940 | 3.153                   |
| 1400                 | 31.22                   | -2,043  | 3.252                   | 172.8 | -30,520 | 3.165                   |
| 1636                 | 0                       | 0       | -                       | 0     | 0       | 0                       |

# CONDITION 2 VERTICAL ANALYSIS

GW 178,800 LB  
 ALT. 15,000 FT.  
 CG 17.0 PERCENT MAC

SPEED 370 KT  
 V<sub>4</sub> 295 KT.  
 M .59

CG ACCELERATION:  
 X .01694 g  
 N. 1.860 PER SEC.

## WING

| WING<br>STATION | $\eta$ | BEAM BENDING MOMENT     |        |                 | BEAM SHEAR |        |                 | TORSION                 |        |                 |
|-----------------|--------|-------------------------|--------|-----------------|------------|--------|-----------------|-------------------------|--------|-----------------|
|                 |        | 10 <sup>3</sup> IN. LB. |        | No.<br>PER SEC. | LB.        |        | No.<br>PER SEC. | 10 <sup>3</sup> IN. LB. |        | No.<br>PER SEC. |
|                 |        | X                       | 19     |                 | X          | 19     |                 | X                       | 19     |                 |
| 0               | 0      | 217.0                   | 15,100 | 1.212           | 604.0      | 54,500 | 1.431           | 69.50                   | -2,900 | 1.719           |
| 94.4            | .12    | 183.5                   | 12,500 | 1.075           | 461.2      | 40,100 | 1.786           | 37.81                   | -1,900 | 2.997           |
| 157.3           | .20    | 160.2                   | 10,600 | .9927           | 435.6      | 33,400 | 1.897           | 37.53                   | -1,300 | 2.945           |
| 259.6           | .33    | 122.0                   | 7,100  | 1.033           | 393.5      | 23,000 | 1.932           | 37.73                   | -940   | 2.154           |
| 322.5           | .41    | 91.15                   | 6,000  | 1.041           | 383.7      | 26,000 | 1.096           | 21.41                   | -550   | 2.375           |
| 432.7           | .55    | 50.26                   | 3,300  | 1.248           | 295.4      | 16,600 | 1.235           | 21.20                   | -630   | 2.296           |
| 503.5           | .64    | 33.18                   | 2,200  | 1.426           | 243.9      | 9,800  | 1.506           | 21.62                   | -600   | 2.208           |
| 550.7           | .70    | 22.26                   | 1,600  | 1.448           | 170.6      | 12,000 | 1.068           | 3.522                   | -100   | 3.151           |
| 645.1           | .82    | 6.566                   | 500    | 2.052           | 88.58      | 6,000  | 1.429           | 1.886                   | -50    | 3.142           |
| 715.9           | .91    | 1.563                   | 100    | 2.816           | 39.66      | 2,500  | 2.107           | .800                    | -10    | 3.534           |

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT          |         |                 | SHEAR |         |                 |
|----------------------------|-------------------------|---------|-----------------|-------|---------|-----------------|
|                            | 10 <sup>3</sup> IN. LB. |         | No.<br>PER SEC. | LB.   |         | No.<br>PER SEC. |
|                            | X                       | 19      |                 | X     | 19      |                 |
| 300                        | 14.79                   | -740    | 4.274           | 167.9 | -10,090 | 3.662           |
| 480                        | 64.38                   | -3,950  | 3.231           | 374.7 | -25,650 | 2.709           |
| 620                        | 122.6                   | -8,226  | 2.836           | 472.0 | -34,900 | 2.255           |
| 720                        | 170.9                   | —       | 2.625           | 531.4 | —       | 1.983           |
| 890                        | 174.0                   | -19,170 | 2.293           | 580.4 | -56,520 | 1.391           |
| 1000                       | 121.8                   | -14,590 | 2.725           | 489.2 | -41,640 | 1.646           |
| 1160                       | 69.94                   | -8,628  | 3.337           | 309.8 | -31,600 | 2.223           |
| 1320                       | 40.36                   | -4,385  | 3.499           | 162.6 | -26,570 | 3.302           |
| 1400                       | 29.09                   | -2,416  | 3.489           | 145.7 | -39,100 | 3.463           |
| 1636                       | 0                       | 0       | —               | 0     | 0       | —               |

CONDITION 2  
 VERTICAL ANALYSIS

# CONDITION 3 VERTICAL ANALYSIS

GW 178,800 LB  
 ALT. 25,000 FT.  
 CG 17.0 PERCENT MAC  
 SPEED 432 KT  
 V<sub>1</sub> 290 KT  
 M .72  
 CG ACCELERATION:  
 X .04630 G  
 Y .1915 PER SEC.  
 Z .1915 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19     |              | $\bar{X}$               | 19     |              |
| 0            | 0      | 208.2                   | 16,900 | 1.209        | 576.3      | 58,000 | 1.395        | 69.46                   | -3,270 | 1.900        |
| 94.4         | .12    | 176.2                   | 13,300 | 1.097        | 439.0      | 43,400 | 1.747        | 40.24                   | -2,100 | 2.969        |
| 157.3        | .20    | 153.7                   | 11,800 | 1.031        | 415.3      | 36,400 | 1.872        | 39.40                   | -1,470 | 2.917        |
| 259.6        | .33    | 117.1                   | 8,100  | 1.131        | 376.6      | 25,000 | 1.973        | 39.12                   | -1,100 | 2.746        |
| 322.5        | .41    | 87.03                   | 6,250  | 1.069        | 369.2      | 27,600 | 1.137        | 21.59                   | -650   | 2.998        |
| 432.7        | .55    | 47.92                   | 3,400  | 1.289        | 283.8      | 17,400 | 1.234        | 21.23                   | -700   | 2.307        |
| 503.5        | .64    | 31.66                   | 2,250  | 1.492        | 235.0      | 10,200 | 1.496        | 21.52                   | -690   | 2.215        |
| 550.7        | .70    | 19.18                   | 1,550  | 1.511        | 161.2      | 13,300 | 1.126        | 36.10                   | -150   | 3.256        |
| 645.1        | .82    | 6.253                   | 500    | 2.155        | 83.70      | 6,000  | 1.515        | 1.901                   | -80    | 3.314        |
| 715.9        | .91    | 1.511                   | 100    | 2.939        | 37.67      | 2,500  | 2.265        | .8225                   | -50    | 3.718        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR     |         |              |
|----------------------|-------------------------|---------|--------------|-----------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.       |         | No. per sec. |
|                      | $\bar{X}$               | 19      |              | $\bar{X}$ | 19      |              |
| 300                  | 13.45                   | -740    | 4.505        | 153.3     | -10,090 | 3.803        |
| 480                  | 58.95                   | -3,950  | 3.291        | 345.6     | -25,650 | 2.688        |
| 620                  | 112.8                   | -8,226  | 2.833        | 439.7     | -34,900 | 2.195        |
| 720                  | 157.9                   | —       | 2.594        | 498.5     | —       | 1.916        |
| 890                  | 167.2                   | -19,920 | 2.264        | 558.6     | -56,750 | 1.402        |
| 1000                 | 116.6                   | -14,710 | 2.709        | 470.4     | -41,870 | 1.649        |
| 1160                 | 66.21                   | -8,716  | 3.388        | 298.2     | -31,830 | 2.205        |
| 1320                 | 38.02                   | -4,436  | 3.624        | 153.0     | -26,800 | 3.370        |
| 1400                 | 27.82                   | -2,449  | 3.598        | 134.2     | -36,590 | 3.665        |
| 1636                 | 0                       | 0       | —            | 0         | 0       | —            |

# CONDITION 3 VERTICAL ANALYSIS

# CONDITION 4 VERTICAL ANALYSIS

OW 166,000 LB  
 ALT. 15,000 FT.  
 CG 18.1 PERCENT MAC

SPEED V<sub>4</sub> 370 KT  
 V<sub>6</sub> 295 KT  
 M .59

CG ACCELERATION:  
 X .01785 g  
 N<sub>z</sub> 1.791 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |        | X                       | 1g     |              | X          | 1g     |              | X                       | 1g     |              |
| 0            | 0      | 221.0                   | 15,300 | 1.161        | 659.7      | 54,400 | 1.366        | 70.18                   | -3,000 | 1.706        |
| 94.4         | 12     | 184.4                   | 11,700 | 1.019        | 496.1      | 41,700 | 1.638        | 58.27                   | -1,830 | 3.037        |
| 157.3        | 20     | 158.7                   | 9,300  | .9532        | 464.7      | 34,100 | 1.687        | 38.13                   | -1,290 | 2.963        |
| 259.6        | 33     | 119.1                   | 6,850  | 1.110        | 390.7      | 22,700 | 1.842        | 38.44                   | -980   | 2.163        |
| 322.5        | 41     | 88.24                   | 5,150  | 1.080        | 377.7      | 25,800 | 1.020        | 21.27                   | -550   | 2.355        |
| 432.7        | 55     | 48.57                   | 2,700  | 1.321        | 286.0      | 13,800 | 1.255        | 21.40                   | -620   | 2.270        |
| 503.5        | 64     | 32.38                   | 1,800  | 1.504        | 237.3      | 7,100  | 1.551        | 21.90                   | -600   | 2.191        |
| 550.7        | 70     | 19.63                   | 1,350  | 1.662        | 164.1      | 10,400 | 1.105        | 3.530                   | -140   | 3.195        |
| 645.1        | 82     | 6.417                   | 400    | 2.054        | 85.46      | 4,950  | 1.422        | 1.875                   | -70    | 3.211        |
| 715.9        | 91     | 1.551                   | 100    | 2.830        | 38.62      | 2,100  | 2.084        | 87.17                   | -40    | 3.624        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR |         |              |
|----------------------|-------------------------|---------|--------------|-------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.   |         | No. per sec. |
|                      | X                       | 1g      |              | X     | 1g      |              |
| 300                  | 15.87                   | -740    | 4.163        | 180.7 | -10,090 | 3.599        |
| 480                  | 69.23                   | -3,950  | 3.263        | 401.7 | -25,650 | 2.693        |
| 620                  | 131.6                   | -8,226  | 2.824        | 504.4 | -34,900 | 2.236        |
| 720                  | 183.2                   | —       | 2.614        | 566.6 | —       | 1.952        |
| 890                  | 189.1                   | -19,670 | 2.374        | 609.1 | -56,370 | 1.313        |
| 1000                 | 133.9                   | -14,510 | 2.802        | 516.0 | -41,490 | 1.630        |
| 1160                 | 77.17                   | -8,571  | 3.375        | 334.6 | -31,450 | 2.309        |
| 1320                 | 43.17                   | -4,352  | 3.535        | 179.7 | -26,470 | 3.359        |
| 1400                 | 30.65                   | -2,395  | 3.518        | 156.7 | -35,780 | 3.525        |
| 1636                 | 0                       | 0       | —            | 0     | 0       | —            |

CONDITION 4  
 VERTICAL ANALYSIS

# CONDITION 5 VERTICAL ANALYSIS

GW 151,800 LB  
 ALT. 15,000 FT.  
 CG 19.6 PERCENT MAC

SPEED 370 KT  
 $V_4$  295 KT  
 $M$  .59

CG ACCELERATION:  
 $\bar{A}$  .01610 g  
 $N$  1.440 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |        | No. PER SEC. | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. |
|              |        | $\bar{A}$               | 19     |              | $\bar{A}$  | 19     |              | $\bar{A}$               | 19     |              |
| 0            | 0      | 209.3                   | 15,400 | 1.075        | 579.6      | 53,500 | 1.478        | 70.74                   | -2,600 | 1.704        |
| 94.4         | 12     | 181.6                   | 12,200 | 9.697        | 431.9      | 38,600 | 1.846        | 30.31                   | -1,690 | 2.983        |
| 157.3        | 20     | 161.1                   | 10,300 | 8.982        | 401.3      | 32,200 | 1.805        | 27.11                   | -1,200 | 3.063        |
| 259.6        | 33     | 123.7                   | 7,600  | 9.632        | 364.2      | 24,100 | 1.549        | 27.54                   | -850   | 2.833        |
| 322.5        | 41     | 94.28                   | 5,850  | 9.908        | 381.2      | 27,400 | 1.9631       | 16.09                   | -450   | 2.195        |
| 432.7        | 55     | 53.78                   | 3,000  | 1.213        | 293.6      | 16,300 | 1.092        | 15.77                   | -550   | 2.105        |
| 503.5        | 64     | 34.04                   | 2,000  | 1.311        | 250.5      | 9,000  | 1.377        | 16.49                   | -550   | 1.993        |
| 560.7        | 70     | 22.28                   | 1,300  | 1.503        | 179.8      | 10,900 | 1.166        | 36.11                   | -110   | 2.422        |
| 645.1        | 82     | 6.927                   | 450    | 1.801        | 100.8      | 5,400  | 1.608        | 2.003                   | -60    | 2.514        |
| 715.3        | 91     | 1.401                   | 100    | 2.020        | 42.27      | 2,450  | 1.933        | 1.038                   | -40    | 2.676        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR     |         |              |
|----------------------|-------------------------|---------|--------------|-----------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. PER SEC. | LB.       |         | No. PER SEC. |
|                      | $\bar{A}$               | 19      |              | $\bar{A}$ | 19      |              |
| 300                  | 13.96                   | -740    | 4.267        | 159.1     | -10,090 | 3.616        |
| 480                  | 60.90                   | -3,950  | 3.171        | 355.8     | -25,650 | 2.677        |
| 620                  | 116.1                   | -8,226  | 2.791        | 447.5     | -34,900 | 2.236        |
| 720                  | 161.9                   | —       | 2.591        | 503.0     | —       | 1.955        |
| 890                  | 182.5                   | -19,250 | 2.508        | 567.8     | -55,730 | 1.542        |
| 1000                 | 131.2                   | -14,160 | 2.823        | 487.0     | -40,850 | 1.878        |
| 1160                 | 77.10                   | -8,327  | 3.183        | 324.3     | -30,810 | 2.473        |
| 1320                 | 42.85                   | -4,210  | 3.213        | 185.4     | -25,780 | 3.180        |
| 1400                 | 29.38                   | -2,304  | 3.176        | 166.6     | -34,420 | 3.244        |
| 1636                 | 0                       | 0       | —            | 0         | 0       | —            |

CONDITION 5

VERTICAL ANALYSIS



# CONDITION 6 VERTICAL ANALYSIS

GW 211,600 LB.  
 ALT. 15,000 FT.  
 CG 20.6 PERCENT MAC

SPEED 370 KT.  
 V 295 KT.  
 M .59

CG ACCELERATION:  
 A .01632 g  
 N. 2.191 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |        | No. PER SEC. | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19     |              | $\bar{X}$               | 19     |              |
| 0            | 0      | 199.4                   | 15,000 | 1.214        | 537.8      | 54,000 | 1.426        | 67.40                   | -2,430 | 1.719        |
| 94.4         | 12     | 173.1                   | 11,000 | 1.112        | 393.1      | 36,400 | 1.869        | 33.75                   | -1,650 | 2.848        |
| 157.3        | 20     | 154.2                   | 10,400 | 1.024        | 378.2      | 29,400 | 2.039        | 31.76                   | -1,240 | 2.914        |
| 259.6        | 33     | 119.9                   | 7,700  | 1.022        | 371.0      | 22,400 | 2.037        | 31.74                   | -800   | 2.754        |
| 322.5        | 41     | 91.22                   | 6,200  | .9858        | 372.1      | 26,000 | 1.285        | 18.75                   | -420   | 2.351        |
| 432.7        | 55     | 51.89                   | 3,500  | 1.216        | 296.6      | 16,300 | 1.181        | 18.26                   | -540   | 2.327        |
| 503.5        | 64     | 34.62                   | 2,400  | 1.375        | 244.8      | 10,900 | 1.442        | 18.62                   | -550   | 2.231        |
| 550.7        | 70     | 21.93                   | 1,700  | 1.581        | 182.5      | 14,200 | 1.203        | 3.252                   | -100   | 2.562        |
| 645.1        | 82     | 6.892                   | 550    | 1.327        | 98.08      | 6,100  | 1.691        | 1.805                   | -50    | 2.501        |
| 715.9        | 91     | 1.515                   | 200    | 2.491        | 42.16      | 3,000  | 1.987        | .8542                   | -20    | 3.006        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR     |         |              |
|----------------------|-------------------------|---------|--------------|-----------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. PER SEC. | LB.       |         | No. PER SEC. |
|                      | $\bar{X}$               | 19      |              | $\bar{X}$ | 19      |              |
| 300                  | 14.53                   | -740    | 4.462        | 161.5     | -10,090 | 3.877        |
| 480                  | 61.06                   | -3,950  | 3.445        | 345.4     | -25,650 | 2.874        |
| 620                  | 113.8                   | -8,226  | 3.022        | 426.5     | -34,900 | 2.340        |
| 720                  | 156.9                   | —       | 2.781        | 476.5     | —       | 2.012        |
| 890                  | 159.4                   | -18,660 | 2.475        | 521.4     | -54,830 | 1.405        |
| 1000                 | 115.6                   | -13,670 | 2.931        | 439.5     | -39,950 | 1.694        |
| 1160                 | 72.11                   | -7,983  | 3.426        | 282.8     | -29,910 | 2.369        |
| 1320                 | 43.70                   | -4,010  | 3.458        | 170.2     | -24,830 | 3.368        |
| 1400                 | 31.13                   | -2,176  | 3.446        | 161.4     | -32,520 | 3.379        |
| 1636                 | 0                       | 0       | —            | 0         | 0       | —            |

CONDITION 6  
VERTICAL ANALYSIS

# CONDITION 7 VERTICAL ANALYSIS

GW 163,800 LB  
 ALT. 30,000 FT.  
 CG 16.4 PERCENT MAC  
 SPEED 480 KT  
 V<sub>1</sub> 294 KT  
 M .82  
 CG ACCELERATION:  
 X .01767 g  
 N 1.872 PER SEC.

| WING STATION | η   | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|-----|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |     | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |     | X                       | 19     |              | X          | 19     |              | X                       | 19     |              |
| 0            | 0   | 219.7                   | 18,100 | 1.224        | 647.9      | 63,400 | 1.391        | 76.09                   | -3,530 | 1.864        |
| 94.4         | .12 | 182.4                   | 13,150 | 1.089        | 502.7      | 48,000 | 1.686        | 46.14                   | -2,490 | 2.982        |
| 157.3        | .20 | 156.0                   | 10,700 | 1.039        | 470.6      | 39,400 | 1.769        | 45.22                   | -1,900 | 2.945        |
| 259.6        | .33 | 117.1                   | 7,550  | 1.231        | 394.9      | 25,500 | 1.949        | 44.41                   | -1,580 | 2.796        |
| 322.5        | .41 | 85.19                   | 5,450  | 1.166        | 371.7      | 27,300 | 1.086        | 23.32                   | -940   | 2.468        |
| 432.7        | .55 | 46.72                   | 3,000  | 1.427        | 281.1      | 14,500 | 1.304        | 23.01                   | -900   | 2.380        |
| 503.5        | .64 | 31.03                   | 2,000  | 1.634        | 236.7      | 7,750  | 1.609        | 23.31                   | -410   | 3.375        |
| 550.7        | .70 | 18.23                   | 1,350  | 1.531        | 153.8      | 11,300 | 1.186        | 4.337                   | -100   | 3.512        |
| 645.1        | .82 | 6.013                   | 400    | 2.200        | 79.49      | 5,000  | 1.488        | 2.203                   | -50    | 3.879        |
| 715.9        | .91 | 1.506                   | 100    | 3.091        | 36.00      | 2,000  | 2.712        | 1.069                   | -50    | 3.879        |

## CONDITION 7 VERTICAL ANALYSIS

| FUSELAGE BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR |         |              |
|-------------------------------|-------------------------|---------|--------------|-------|---------|--------------|
|                               | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.   |         | No. per sec. |
|                               | X                       | 19      |              | X     | 19      |              |
| 300                           | 15.36                   | -739    | 4.336        | 176.2 | -10,540 | 3.613        |
| 480                           | 67.72                   | -3,948  | 3.238        | 395.1 | -24,920 | 2.669        |
| 620                           | 129.5                   | -7,968  | 2.815        | 500.1 | -31,540 | 2.206        |
| 720                           | 180.8                   | —       | 2.590        | 564.3 | —       | 1.933        |
| 890                           | 195.2                   | -20,150 | 2.288        | 624.4 | -55,200 | 1.375        |
| 1000                          | 137.1                   | -15,000 | 2.690        | 529.6 | -41,790 | 1.658        |
| 1160                          | 76.54                   | -8,949  | 3.322        | 345.5 | -32,440 | 2.259        |
| 1320                          | 41.48                   | -4,572  | 3.645        | 117.2 | -27,410 | 3.333        |
| 1400                          | 29.98                   | -2,536  | 3.624        | 147.1 | -37,880 | 3.752        |
| 1636                          | 0                       | 0       | —            | 0     | 0       | —            |

# CONDITION 8 VERTICAL ANALYSIS

GW 163,800 LB  
 ALT. 35,000 FT.  
 CG 16.4 PERCENT MAC  
 SPEED 475 KT.  
 V<sub>g</sub> 263 KT.  
 M .82  
 CG ACCELERATION:  
 X .01573 g  
 N<sub>y</sub> 1.807 PER SEC.

## WING

| WING<br>STATION | $\eta$ | BEAM BENDING MOMENT     |        |                            | BEAM SHEAR |        |                            | TORSION                 |        |                            |
|-----------------|--------|-------------------------|--------|----------------------------|------------|--------|----------------------------|-------------------------|--------|----------------------------|
|                 |        | 10 <sup>3</sup> IN. LB. |        | N <sub>y</sub><br>PER SEC. | LB.        |        | N <sub>y</sub><br>PER SEC. | 10 <sup>3</sup> IN. LB. |        | N <sub>y</sub><br>PER SEC. |
|                 |        | X                       | 1g     |                            | X          | 1g     |                            | X                       | 1g     |                            |
| 0               | 0      | 202.8                   | 17,200 | 1.115                      | 570.0      | 60,300 | 1.248                      | 14.23                   | -3,700 | 1.790                      |
| 94.4            | .12    | 171.1                   | 13,400 | 1.029                      | 443.3      | 46,400 | 1.501                      | 43.47                   | -2,450 | 2.869                      |
| 157.3           | .20    | 147.3                   | 11,200 | 1.012                      | 417.8      | 38,400 | 1.569                      | 41.94                   | -1,740 | 2.872                      |
| 259.6           | .33    | 110.6                   | 7,950  | 1.188                      | 355.1      | 25,500 | 1.739                      | 41.13                   | -1,360 | 2.732                      |
| 322.5           | .41    | 81.19                   | 5,900  | 1.148                      | 348.1      | 28,000 | 1.054                      | 21.97                   | -150   | 2.362                      |
| 432.7           | .55    | 44.93                   | 3,200  | 1.396                      | 265.8      | 15,800 | 1.236                      | 21.47                   | -800   | 2.285                      |
| 503.5           | .64    | 30.02                   | 2,200  | 1.615                      | 222.8      | 9,000  | 1.497                      | 21.62                   | -750   | 2.257                      |
| 550.7           | .70    | 17.15                   | 1,500  | 1.500                      | 146.3      | 12,300 | 1.162                      | 3.923                   | -120   | 3.125                      |
| 645.1           | .82    | 5.861                   | 400    | 2.073                      | 77.57      | 5,600  | 1.446                      | 2.000                   | -80    | 3.210                      |
| 715.9           | .91    | 1.443                   | 200    | 2.864                      | 35.26      | 2,200  | 2.105                      | .9757                   | -40    | 3.550                      |

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT          |         |                            | SHEAR |         |                            |
|----------------------------|-------------------------|---------|----------------------------|-------|---------|----------------------------|
|                            | 10 <sup>3</sup> IN. LB. |         | N <sub>y</sub><br>PER SEC. | LB.   |         | N <sub>y</sub><br>PER SEC. |
|                            | X                       | 1g      |                            | X     | 1g      |                            |
| 300                        | 12.66                   | -706    | 4.325                      | 145.4 | -10,140 | 3.659                      |
| 480                        | 56.09                   | -3,852  | 3.211                      | 330.4 | -24,690 | 2.598                      |
| 620                        | 107.9                   | -7,856  | 2.759                      | 422.4 | -31,550 | 2.101                      |
| 720                        | 151.3                   | -       | 2.517                      | 480.2 | -       | 1.813                      |
| 890                        | 176.1                   | -19,190 | 2.154                      | 563.3 | -53,950 | 1.248                      |
| 1000                       | 123.4                   | -14,220 | 2.563                      | 477.3 | -40,390 | 1.517                      |
| 1160                       | 68.34                   | -8,376  | 3.221                      | 310.9 | -30,940 | 2.121                      |
| 1320                       | 36.60                   | -4,239  | 3.582                      | 159.1 | -25,910 | 3.230                      |
| 1400                       | 26.34                   | -2,323  | 3.567                      | 131.4 | -34,700 | 3.651                      |
| 1636                       | 0                       | 0       | -                          | 0     | 0       | -                          |

CONDITION 8

VERTICAL ANALYSIS

# CONDITION 9 VERTICAL ANALYSIS

OW 163,800 LB. CG ACCELERATION: X .01377 g  
ALT. 40,000 FT. Y 475 KT. N 1.725 PER SEC.  
CG 16.4 PERCENT MAC M .82

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR              |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|-------------------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. | X      | No. per sec. | 10 <sup>3</sup> IN. LB. | X      | No. per sec. | 10 <sup>3</sup> IN. LB. | X      | No. per sec. |
|              |        |                         |        |              |                         |        |              |                         |        |              |
| 0            | 0      | 184.9                   | 17,200 | 1.053        | 497.9                   | 56,100 | 1.146        | 68.77                   | -3,880 | 1.464        |
| 94.4         | .12    | 158.0                   | 13,600 | .9911        | 390.1                   | 44,300 | 1.367        | 57.62                   | -2,380 | 2.802        |
| 157.3        | .20    | 136.5                   | 11,400 | .9866        | 370.5                   | 37,200 | 1.420        | 35.99                   | -1,680 | 2.800        |
| 229.6        | .33    | 102.6                   | 8,250  | 1.144        | 318.2                   | 25,800 | 1.577        | 35.59                   | -1,160 | 2.953        |
| 322.5        | .41    | 75.89                   | 6,200  | 1.123        | 319.6                   | 28,500 | 1.019        | 19.86                   | -560   | 2.293        |
| 432.7        | .55    | 42.42                   | 3,400  | 1.365        | 246.7                   | 16,600 | 1.183        | 19.39                   | -670   | 2.192        |
| 503.5        | .64    | 28.66                   | 2,400  | 1.613        | 206.5                   | 10,000 | 1.415        | 19.50                   | -700   | 2.119        |
| 550.7        | .70    | 16.92                   | 1,580  | 1.469        | 140.3                   | 13,000 | 1.149        | 3.456                   | -90    | 2.895        |
| 645.1        | .82    | 5.585                   | 500    | 1.957        | 14.09                   | 6,000  | 1.412        | 1.766                   | -40    | 2.927        |
| 715.2        | .91    | 1.361                   | 100    | 2.657        | 33.75                   | 2,450  | 1.963        | 8.682                   | -10    | 3.244        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR                   |         |              |
|----------------------|-------------------------|---------|--------------|-------------------------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. | X       | No. per sec. | 10 <sup>3</sup> IN. LB. | X       | No. per sec. |
|                      |                         |         |              |                         |         |              |
| 300                  | 10.44                   | -676    | 4.264        | 120.2                   | -9,782  | 3.613        |
| 480                  | 46.54                   | -3,767  | 3.168        | 276.3                   | -24,470 | 2.533        |
| 620                  | 89.97                   | -7,151  | 2.704        | 356.3                   | -31,530 | 2.019        |
| 720                  | 126.7                   | —       | 2.452        | 407.5                   | —       | 1.721        |
| 890                  | 157.3                   | -18,370 | 2.041        | 502.5                   | -52,890 | 1.158        |
| 1000                 | 109.9                   | -13,530 | 2.445        | 476.0                   | -39,180 | 1.412        |
| 1160                 | 60.24                   | -7,887  | 3.115        | 277.9                   | -29,660 | 2.007        |
| 1320                 | 31.79                   | -3,955  | 3.509        | 142.2                   | -24,630 | 3.113        |
| 1400                 | 22.85                   | -2,141  | 3.499        | 116.7                   | -31,990 | 3.527        |
| 1636                 | 0                       | 0       | —            | 0                       | 0       | —            |

CONDITION 9

VERTICAL ANALYSIS

# CONDITION 10 VERTICAL ANALYSIS

GW 204,200 LB.      SPEED 475 KT      CG ACCELERATION:  $\bar{X}$  .0147G  $\bar{N}$  2.25G PER SEC.  
 ALT. 35,000 FT.       $V$  263 KT.  
 CG 21.5 PERCENT MAC       $M$  .82

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |        | No. PER SEC. | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19     |              | $\bar{X}$               | 19     |              |
| 0            | 0      | 184.5                   | 16,100 | 1.113        | 485.0      | 51,300 | 1.129        | 68.59                   | -2,760 | 1.677        |
| 94.4         | .12    | 160.9                   | 12,700 | 1.089        | 353.9      | 41,300 | 1.465        | 34.64                   | -1,880 | 2.716        |
| 157.3        | .20    | 142.1                   | 10,900 | 1.050        | 339.7      | 33,600 | 1.689        | 32.05                   | -1,430 | 2.774        |
| 259.6        | .33    | 108.3                   | 8,000  | 1.039        | 329.6      | 23,500 | 1.863        | 31.97                   | -1,140 | 2.633        |
| 322.5        | .41    | 81.92                   | 6,300  | 1.016        | 338.8      | 26,100 | 1.511        | 19.28                   | -560   | 2.295        |
| 432.7        | .55    | 46.24                   | 3,600  | 1.246        | 272.0      | 16,500 | 1.48         | 18.51                   | -700   | 2.276        |
| 503.5        | .64    | 31.14                   | 2,400  | 1.482        | 226.3      | 10,800 | 1.571        | 18.57                   | -700   | 2.191        |
| 550.1        | .70    | 19.33                   | 1,630  | 1.630        | 163.2      | 14,300 | 1.269        | 3.474                   | -      | 90           |
| 645.1        | .82    | 6.039                   | 500    | 1.983        | 87.07      | 6,900  | 1.731        | 1.828                   | -      | 50           |
| 715.9        | .91    | 1.309                   | 100    | 2.607        | 37.24      | 3,000  | 2.081        | 32.04                   | -      | 40           |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |          |              | SHEAR     |          |              |
|----------------------|-------------------------|----------|--------------|-----------|----------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |          | No. PER SEC. | LB.       |          | No. PER SEC. |
|                      | $\bar{X}$               | 19       |              | $\bar{X}$ | 19       |              |
| 300                  | 1096                    | - 666    | 4.905        | 122.9     | - 976    | 4.135        |
| 480                  | 4687                    | - 3,739  | 3.578        | 271.9     | - 24,230 | 2.741        |
| 620                  | 8880                    | - 7,665  | 2.972        | 346.7     | - 30,760 | 2.038        |
| 720                  | 124.0                   | -        | 2.630        | 396.6     | -        | 1.649        |
| 820                  | 149.8                   | - 17,520 | 2.194        | 490.1     | - 51,220 | 1.226        |
| 1000                 | 1064                    | - 12,840 | 2.693        | 412.7     | - 37,780 | 1.476        |
| 1140                 | 6230                    | - 7,402  | 3.411        | 266.8     | - 28,330 | 2.150        |
| 1320                 | 35.77                   | - 3,673  | 3.688        | 147.8     | - 23,360 | 3.365        |
| 1400                 | 25.78                   | - 1,961  | 3.664        | 131.2     | - 29,300 | 3.668        |
| 1636                 | 0                       | -        | -            | 0         | 0        | -            |

CONDITION 10  
 VERTICAL ANALYSIS

# CONDITION 11 VERTICAL ANALYSIS

GW 183,000 LB. ALT. 35,000 FT. CG 19.4 PERCENT MAC

SPEED V<sub>4</sub> 280 KT. V<sub>6</sub> 263 KT. M .82

CG ACCELERATION: X .01467 g N<sub>0</sub> 1.599 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |        | X                       | 19     |              | X          | 19     |              | X                       | 19     |              |
| 0            | 0      | 196.1                   | 16,600 | 1.037        | 527.7      | 51,500 | 1.195        | 69.60                   | -3,180 | 1.530        |
| 94.4         | .12    | 169.5                   | 13,900 | .973         | 396.4      | 43,300 | 1.470        | 30.79                   | -2,170 | 2.772        |
| 157.3        | .20    | 148.2                   | 10,900 | .945         | 311.1      | 35,800 | 1.514        | 28.71                   | -1,560 | 2.805        |
| 259.6        | .33    | 112.3                   | 7,900  | 1.013        | 335.9      | 24,600 | 1.504        | 29.47                   | -1,250 | 2.592        |
| 322.5        | .41    | 84.91                   | 6,000  | 1.039        | 348.0      | 27,500 | 1.014        | 18.39                   | -640   | 2.136        |
| 432.7        | .55    | 48.07                   | 3,200  | 1.267        | 274.4      | 16,100 | 1.124        | 17.96                   | -730   | 2.077        |
| 503.5        | .64    | 31.18                   | 2,450  | 1.485        | 236.2      | 9,000  | 1.347        | 18.58                   | -720   | 1.992        |
| 550.7        | .70    | 19.59                   | 1,600  | 1.496        | 163.0      | 11,500 | 1.263        | 3.60                    | -100   | 2.531        |
| 645.1        | .82    | 5.772                   | 440    | 1.686        | 88.4       | 5,500  | 1.954        | 16.79                   | -60    | 2.556        |
| 715.5        | .91    | 1.166                   | 100    | 2.023        | 35.00      | 2,500  | 1.840        | 9.861                   | -40    | 3.002        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR |         |              |
|----------------------|-------------------------|---------|--------------|-------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.   |         | No. per sec. |
|                      | X                       | 19      |              | X     | 19      |              |
| 300                  | 10.39                   | -690    | 4.667        | 120.7 | -9,900  | 3.770        |
| 480                  | 47.04                   | -3,808  | 3.181        | 285.7 | -24,510 | 2.463        |
| 620                  | 92.17                   | -7,782  | 2.636        | 373.2 | -31,240 | 1.954        |
| 720                  | 130.8                   | —       | 2.366        | 429.8 | —       | 1.646        |
| 890                  | 162.1                   | -17,430 | 2.076        | 529.7 | -51,190 | 1.260        |
| 1000                 | 112.4                   | -12,760 | 2.450        | 448.3 | -37,680 | 1.531        |
| 1160                 | 61.15                   | -7,349  | 3.073        | 288.4 | -28,250 | 2.070        |
| 1320                 | 22.34                   | -3,642  | 3.424        | 145.1 | -23,220 | 3.081        |
| 1400                 | 22.65                   | -1,941  | 3.418        | 122.5 | -29,000 | 3.493        |
| 1636                 | 0                       | 0       | —            | 0     | 0       | —            |

CONDITION 11  
VERTICAL ANALYSIS

# CONDITION 12 VERTICAL ANALYSIS

QW 159,000 LB  
 ALT. 10,000 FT.  
 CG 17.0 PERCENT MAC

SPEED 310 KT  
 W 310 KT  
 V 264 KT  
 M .48

CG ACCELERATION:  
 X .01673  
 N 1.170 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |        | X                       | 19     |              | X          | 19     |              | X                       | 19     |              |
| 0            | 0      | 213.5                   | 15,000 | 1.113        | 597.7      | 51,500 | 1.318        | 68.90                   | -3,750 | 1.509        |
| 94.4         | 12     | 180.2                   | 11,100 | .9828        | 467.9      | 40,400 | 1.574        | 34.63                   | -2,500 | 2.925        |
| 157.3        | 20     | 155.7                   | 9,800  | .9256        | 440.7      | 34,100 | 1.606        | 34.36                   | -1,850 | 2.953        |
| 259.6        | 33     | 117.1                   | 6,900  | 1.064        | 374.1      | 23,500 | 1.752        | 54.97                   | -1,500 | 2.737        |
| 322.5        | 41     | 87.35                   | 5,000  | 1.040        | 367.8      | 23,100 | .9960        | 19.82                   | -700   | 2.257        |
| 432.7        | 55     | 48.36                   | 2,800  | 1.260        | 280.8      | 13,100 | 1.217        | 19.26                   | -790   | 2.193        |
| 503.5        | 64     | 32.19                   | 2,000  | 1.430        | 231.9      | 7,000  | 1.492        | 20.46                   | -800   | 2.123        |
| 550.7        | 70     | 19.73                   | 1,300  | 1.413        | 164.2      | 10,000 | 1.034        | 3.131                   | -70    | 2.818        |
| 645.1        | 82     | 6.435                   | 400    | 1.941        | 86.46      | 5,000  | 1.367        | 1.702                   | -40    | 2.719        |
| 715.2        | 91     | 1.526                   | 200    | 2.631        | 38.96      | 2,500  | 1.929        | .7868                   | -10    | 3.097        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR |         |              |
|----------------------|-------------------------|---------|--------------|-------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.   |         | No. per sec. |
|                      | X                       | 19      |              | X     | 19      |              |
| 300                  | 15.16                   | -740    | 3.958        | 172.0 | -10,000 | 3.474        |
| 480                  | 65.70                   | -3,950  | 3.151        | 378.4 | -25,650 | 2.665        |
| 620                  | 124.3                   | -8,226  | 2.803        | 471.8 | -34,900 | 2.226        |
| 720                  | 172.4                   | —       | 2.602        | 527.7 | —       | 1.939        |
| 890                  | 184.2                   | -19,260 | 2.324        | 575.3 | -55,740 | 1.232        |
| 1000                 | 132.4                   | -14,170 | 2.743        | 488.9 | -40,860 | 1.521        |
| 1160                 | 78.11                   | -8,330  | 3.285        | 322.6 | -30,820 | 2.233        |
| 1320                 | 43.75                   | -4,212  | 3.448        | 183.8 | -25,790 | 3.254        |
| 1400                 | 30.62                   | -2,366  | 3.458        | 162.2 | -34,450 | 3.353        |
| 1636                 | 0                       | 0       | —            | 0     | 0       | —            |

CONDITION 12  
VERTICAL ANALYSIS

# CONDITION 13 VERTICAL ANALYSIS

GW 159,000 LB. SPEED 380 KT. CG ACCELERATION:  
ALT. 20,000 FT.  $V_f$  277 KT.  $\bar{X}$  .0165g  
CG 17.0 PERCENT MAC  $V_0$  M .62 N. 1.784 PER SEC.

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19     |              | $\bar{X}$               | 19     |              |
| 0            | 0      | 209.5                   | 15,400 | 1,134        | 592.9      | 54,900 | 1,327        | 68.11                   | -3,720 | 1,690        |
| 94.4         | .12    | 176.0                   | 11,900 | 1,008        | 461.7      | 42,300 | 1,586        | 36.92                   | -2,550 | 2,996        |
| 157.3        | .20    | 151.8                   | 9,900  | 957.9        | 434.3      | 35,700 | 1,624        | 36.54                   | -1,980 | 2,937        |
| 259.6        | .33    | 114.2                   | 7,900  | 1,108        | 367.7      | 24,400 | 1,775        | 36.79                   | -1,600 | 2,737        |
| 322.5        | .41    | 84.75                   | 5,900  | 1,082        | 359.4      | 24,400 | 1,014        | 20.36                   | -      | 800          |
| 432.7        | .55    | 46.91                   | 2,600  | 1,920        | 273.7      | 13,000 | 1,230        | 20.42                   | -      | 850          |
| 503.5        | .64    | 31.30                   | 1,800  | 1,508        | 227.2      | 9,400  | 1,509        | 20.84                   | -      | 850          |
| 550.7        | .70    | 18.93                   | 1,200  | 1,448        | 157.6      | 10,000 | 1,105        | 3.317                   | -      | 100          |
| 645.1        | .82    | 6.191                   | 400    | 2,000        | 82.65      | 4,600  | 1,411        | 1.764                   | -      | 50           |
| 715.9        | .91    | 1.491                   | 100    | 2,739        | 37.52      | 2,000  | 2,036        | .8308                   | -      | 10           |

## CONDITION 13 VERTICAL ANALYSIS

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR     |         |              |
|----------------------|-------------------------|---------|--------------|-----------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.       |         | No. per sec. |
|                      | $\bar{X}$               | 19      |              | $\bar{X}$ | 19      |              |
| 300                  | 14.40                   | -740    | 4,149        | 164.2     | -10,090 | 3,597        |
| 480                  | 62.94                   | -3,950  | 3,200        | 365.8     | -25,600 | 2,679        |
| 620                  | 113.8                   | -8,220  | 2,815        | 460.5     | -34,900 | 2,212        |
| 720                  | 167.0                   | -       | 2,600        | 518.5     | -       | 1,922        |
| 890                  | 177.3                   | -19,910 | 2,331        | 570.5     | -56,830 | 1,277        |
| 1000                 | 125.4                   | -14,760 | 2,761        | 483.3     | -41,950 | 1,589        |
| 1160                 | 71.82                   | -8,747  | 3,352        | 313.9     | -31,910 | 2,267        |
| 1320                 | 39.87                   | -4,454  | 3,540        | 167.8     | -26,880 | 3,340        |
| 1400                 | 28.29                   | -2,460  | 3,523        | 145.2     | -36,760 | 3,536        |
| 1636                 | 0                       | 0       | -            | 0         | 0       | -            |



# CONDITION 14 VERTICAL ANALYSIS

QW 119,700 LB  
 ALT. 22,000 FT.  
 CG 20.6 PERCENT MAC  
 SPEED V<sub>T</sub> 532 KT  
 V<sub>6</sub> 375 KT  
 M .87  
 CG ACCELERATION:  
 A .027876 g  
 N 2.283 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 181.637                 | 12,500 | 1.237        | 672.057    |    | 1.883        | 72.753                  |    | 2.143        |
| 94.4         | .12    | 143.173                 | 9,250  | 1.537        | 513.521    |    | 2.293        | 54.550                  |    | 3.029        |
| 157.3        | .20    | 119.079                 | 7,220  | 1.337        | 478.915    |    | 2.396        | 54.036                  |    | 2.975        |
| 259.6        | .33    | 89.448                  | 4,520  | 1.604        | 375.232    |    | 2.836        | 52.029                  |    | 2.820        |
| 322.5        | .41    | 61.317                  | 3,000  | 1.589        | 287.855    |    | 1.341        | 24.419                  |    | 2.115        |
| 432.7        | .55    | 34.130                  | 1,300  | 2.066        | 189.621    |    | 1.873        | 25.214                  |    | 2.917        |
| 503.5        | .64    | 27.157                  | 950    | 2.127        | 174.021    |    | 2.404        | 25.808                  |    | 2.763        |
| 550.7        | .70    | 14.400                  | 650    | 2.140        | 124.696    |    | 1.789        | 8.583                   |    | 4.031        |
| 645.1        | .82    | 5.043                   | 200    | 3.363        | 62.791     |    | 2.070        | 3.452                   |    | 4.336        |
| 715.9        | .91    | 1.537                   | 0      | 4.623        | 22.241     |    | 3.366        | 1.796                   |    | 4.674        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300                  | 26.399                  |    | 4.302        | 292.246   |    | 3.695        |
| 480                  | 100.376                 |    | 3.402        | 502.224   |    | 3.011        |
| 620                  | 174.424                 |    | 3.130        | 569.260   |    | 2.686        |
| 720                  | 232.757                 |    | 2.972        | 630.928   |    | 2.392        |
| 890                  | 238.288                 |    | 2.709        | 645.492   |    | 1.898        |
| 1000                 | 178.705                 |    | 3.061        | 548.800   |    | 2.232        |
| 1160                 | 106.712                 |    | 3.541        | 439.511   |    | 2.599        |
| 1320                 | 66.998                  |    | 3.957        | 260.164   |    | 3.419        |
| 1400                 | 40.285                  |    | 4.001        | 203.496   |    | 4.024        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 14  
 VERTICAL ANALYSIS

# CONDITION 15 VERTICAL ANALYSIS

OW 156,000 LB. ALT. 23,000 FT. CG 15.6 PERCENT MAC

SPEED V<sub>Y</sub> 532 KT. V<sub>E</sub> 375 KT. M 1.87

CG ACCELERATION: A .023326 g N. 2.189 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |    | No. per sec. | 10 <sup>3</sup> IN. LB. |    | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 261.938                 | 17850  | 1.434        | 878.432    |    | 1.502        | 93.563                  |    | 1.607        |
| 94.4         | .12    | 267.491                 | 13,400 | 1.264        | 700.419    |    | 1.776        | 48.812                  |    | 2.934        |
| 157.3        | .20    | 168.747                 | 10,350 | 1.149        | 494.459    |    | 1.879        | 47.982                  |    | 2.969        |
| 259.6        | .33    | 119.022                 | 6,440  | 1.810        | 487.608    |    | 2.233        | 47.602                  |    | 2.831        |
| 372.5        | .41    | 83.103                  | 4,200  | 1.308        | 407.799    |    | 1.141        | 28.762                  |    | 2.820        |
| 432.7        | .55    | 44.313                  | 2,020  | 1.638        | 287.603    |    | 1.489        | 20.834                  |    | 2.733        |
| 503.5        | .64    | 29.737                  | 1,850  | 1.933        | 252.246    |    | 1.890        | 29.079                  |    | 2.636        |
| 550.7        | .70    | 16.479                  | 820    | 1.732        | 144.478    |    | 1.578        | 6.593                   |    | 1.020        |
| 645.1        | .82    | 5.550                   | 300    | 2.908        | 71.839     |    | 1.645        | 3.473                   |    | 4.312        |
| 715.9        | .91    | 1.619                   | 100    | 4.360        | 32.481     |    | 2.861        | 1.806                   |    | 4.653        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR     |         |              |
|----------------------|-------------------------|---------|--------------|-----------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.       |         | No. per sec. |
|                      | $\bar{X}$               | 19      |              | $\bar{X}$ | 19      |              |
| 300                  | 21.771                  | -568    | 4.787        | 244.906   | -10,874 | 2.189        |
| 480                  | 92.581                  | -3,961  | 3.683        | 524.154   | -25,332 | 4.068        |
| 620                  | 173.465                 | -8,079  | 3.118        | 657.896   | -32,564 | 2.981        |
| 720                  | 240.648                 | —       | 2.851        | 750.936   | —       | 2.431        |
| 890                  | 262.599                 | -25,523 | 2.500        | 809.619   | -57,685 | 2.077        |
| 1000                 | 185.006                 | -19,478 | 3.038        | 720.233   | -53,475 | 1.542        |
| 1160                 | 106.597                 | -11,973 | 3.594        | 444.084   | -41,026 | 1.904        |
| 1320                 | 59.883                  | -6,294  | 3.790        | 217.839   | -21,010 | 2.624        |
| 1400                 | 43.031                  | -2,906  | 3.747        | 211.297   | -55,958 | 3.608        |
| 1636                 | 0                       | 0       | —            | 0         | 0       | —            |

CONDITION 15  
VERTICAL ANALYSIS

# CONDITION 16 VERTICAL ANALYSIS

GW 186,000 LB.      SPEED 532 KT      CG ACCELERATION:  $\bar{X}$  .02206g  
 ALI 22,000 FT.       $V_4$  375 KT.       $N_4$  2.49% PER SEC.  
 CG 16.3 PERCENT MAC      M .87

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19     |              | $\bar{X}$               | 19     |              |
| 0            | 0      | 261.8                   |        | 1.599        | 843.8      |        | 1.830        | 99.36                   |        | 2.019        |
| 94.4         | .12    | 213.5                   | 14,100 | 1.425        | 655.2      | 51,500 | 2.258        | 56.14                   | -4,500 | 3.044        |
| 157.3        | .20    | 179.3                   | 11,400 | 1.260        | 607.2      | 44,500 | 2.421        | 53.61                   | -3,400 | 3.044        |
| 239.6        | .33    | 130.8                   | 7,500  | 1.296        | 515.1      | 27,000 | 2.474        | 52.09                   | -2,500 | 2.919        |
| 322.5        | .41    | 93.35                   | 5,600  | 1.207        | 435.1      | 21,600 | 1.378        | 29.96                   | -1,750 | 2.185        |
| 432.7        | .56    | 49.33                   | 2,600  | 1.499        | 324.6      | 13,600 | 1.440        | 28.61                   | -1,300 | 2.697        |
| 503.5        | .64    | 31.36                   | 1,700  | 1.735        | 279.2      | 6,560  | 1.826        | 28.53                   | -1,040 | 2.587        |
| 550.7        | .70    | 18.87                   | 1,100  | 1.977        | 165.6      | 2,000  | 1.571        | 64.27                   | -480   | 3.935        |
| 645.1        | .82    | 6.209                   | 300    | 3.003        | 83.95      | 3,100  | 2.028        | 33.73                   | -250   | 4.213        |
| 715.9        | .91    | 1.637                   | 100    | 4.296        | 37.91      | 500    | 3.119        | 1.724                   | -100   | 4.578        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR     |         |              |
|----------------------|-------------------------|---------|--------------|-----------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. per sec. | LB.       |         | No. per sec. |
|                      | $\bar{X}$               | 19      |              | $\bar{X}$ | 19      |              |
| 300                  | 23.17                   | - 728   | 4.722        | 2569      | -10,480 | 4.097        |
| 480                  | 95.95                   | - 3843  | 3.683        | 524.9     | -24,860 | 3.171        |
| 620                  | 175.7                   | - 7,884 | 3.288        | 636.4     | -31,790 | 2.683        |
| 720                  | 239.8                   | —       | 3.061        | 709.9     | —       | 2.352        |
| 890                  | 271.6                   | -25,270 | 2.806        | 829.8     | -57,020 | 1.901        |
| 1000                 | 198.2                   | -19,280 | 3.156        | 708.1     | -52,040 | 2.203        |
| 1160                 | 119.6                   | -11,830 | 3.572        | 480.5     | -40,660 | 2.818        |
| 1320                 | 67.91                   | - 6,212 | 3.725        | 283.3     | -30,640 | 3.560        |
| 1400                 | 48.29                   | - 3,854 | 3.719        | 246.6     | -55,170 | 3.828        |
| 1636                 | 0                       | 0       | —            | 0         | 0       | —            |

CONDITION 16  
VERTICAL ANALYSIS

# CONDITION 17 VERTICAL ANALYSIS

OW 221,600 LB. ALT. 22,000 FT. CG 16.3 PERCENT MAC

SPEED V<sub>1</sub> 692 KT. V<sub>e</sub> 975 KT. M .87

CG ACCELERATION:  $\Delta$  .020111 g N. 2.190 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> N. IN. |    | No. PER SEC. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$              | 19 |              |
| 0            | 0      | 232.815                 | 17,350 | 1.176        | 693.894    |    | 1.264        | 21.608                 |    | 1.036        |
| 94.4         | .12    | 241.777                 | 13,800 | 1.164        | 471.982    |    | 1.528        | 26.973                 |    | 2.632        |
| 157.3        | .20    | 176.532                 | 11,250 | 1.127        | 433.554    |    | 1.793        | 35.755                 |    | 2.811        |
| 259.6        | .33    | 133.500                 | 7,350  | 1.121        | 413.132    |    | 1.932        | 34.282                 |    | 2.708        |
| 322.5        | .41    | 99.894                  | 5,300  | 1.112        | 425.316    |    | 1.361        | 22.033                 |    | 2.247        |
| 432.7        | .55    | 55.643                  | 2,680  | 1.355        | 332.056    |    | 1.235        | 20.458                 |    | 2.343        |
| 503.5        | .64    | 34.961                  | 1,800  | 1.543        | 282.020    |    | 1.444        | 20.630                 |    | 2.223        |
| 550.7        | .70    | 22.369                  | 1,100  | 1.961        | 185.953    |    | 1.366        | 6.665                  |    | 3.036        |
| 665.1        | .82    | 7.018                   | 470    | 2.579        | 102.678    |    | 2.118        | 3.607                  |    | 2.542        |
| 715.9        | .91    | 1.568                   | 200    | 3.089        | 44.546     |    | 2.933        | 2.003                  |    | 2.680        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |         |              | SHEAR     |         |              |
|----------------------|-------------------------|---------|--------------|-----------|---------|--------------|
|                      | 10 <sup>3</sup> IN. LB. |         | No. PER SEC. | LB.       |         | No. PER SEC. |
|                      | $\bar{X}$               | 19      |              | $\bar{X}$ | 19      |              |
| 300                  | 15.080                  | -697    | 6.019        | 163.464   | -19,184 | 4.941        |
| 480                  | 41.403                  | -3,752  | 4.135        | 342.476   | -24,597 | 3.164        |
| 620                  | 114.571                 | -7,733  | 3.365        | 450.222   | -31,205 | 2.285        |
| 720                  | 159.917                 | —       | 2.927        | 530.661   | —       | 1.790        |
| 850                  | 194.148                 | -24,133 | 2.372        | 696.732   | -55,092 | 1.461        |
| 1000                 | 135.241                 | -18,341 | 2.881        | 573.583   | -50,276 | 1.819        |
| 1160                 | 52.232                  | -11,175 | 3.495        | 347.247   | -38,936 | 2.487        |
| 1320                 | 50.901                  | -5,830  | 3.624        | 197.083   | -28,920 | 3.573        |
| 1400                 | 36.410                  | -3,609  | 2.568        | 123.305   | -51,528 | 3.859        |
| 1636                 | 0                       | 0       | —            | 0         | 0       | —            |

CONDITION 17  
VERTICAL ANALYSIS

# CONDITION 18 VERTICAL ANALYSIS

GW 186,000 LB. ALT. 5,000 FT. CG 16.3 PERCENT MAC  
 SPEED V<sub>T</sub> 403 KT. V<sub>E</sub> 375 KT. M .62  
 CG ACCELERATION:  $\bar{A}$  .021832 g N<sub>0</sub> 1.996 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. |
|              |        | $\bar{A}$               | 19     |              | $\bar{A}$  | 19 |              | $\bar{A}$               | 19 |              |
| 0            | 0      | 265.404                 | 16,000 | 1.320        | 841.600    |    | 1.529        | 76.721                  |    | 1.971        |
| 90.4         | .12    | 218.921                 | 12,000 | 1.223        | 636.030    |    | 1.984        | 41.5                    |    | 3.131        |
| 157.3        | .20    | 187.099                 | 9,800  | 1.071        | 587.748    |    | 2.152        | 42.284                  |    | 3.016        |
| 252.6        | .33    | 192.471                 | 7,000  | 1.127        | 564.337    |    | 2.318        | 42.233                  |    | 3.723        |
| 372.5        | .41    | 102.472                 | 5,000  | 1.061        | 455.489    |    | 1.146        | 27.055                  |    | 2.646        |
| 432.7        | .55    | 54.950                  | 2,700  | 1.294        | 330.936    |    | 1.322        | 26.632                  |    | 2.650        |
| 503.5        | .64    | 35.822                  |        | 1.481        | 282.842    |    | 1.688        | 27.086                  |    | 2.434        |
| 550.7        | .70    | 21.511                  |        | 1.569        | 186.052    |    | 1.195        | 4.723                   |    | 3.111        |
| 645.1        | .82    | 6.245                   |        | 2.426        | 23.615     |    | 1.524        | 2.464                   |    | 3.970        |
| 715.9        | .91    | 1.702                   |        | 3.451        | 41.554     |    | 2.606        | 1.138                   |    | 4.106        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{A}$               | 19 |              | $\bar{A}$ | 19 |              |
| 300                  | 20.082                  |    | 4.663        | 227.343   |    | 3.900        |
| 480                  | 87.217                  |    | 3.364        | 509.650   |    | 2.817        |
| 620                  | 166.720                 |    | 2.920        | 651.641   |    | 2.327        |
| 720                  | 224.101                 |    | 2.686        | 748.174   |    | 2.031        |
| 890                  | 216.535                 |    | 2.623        | 761.318   |    | 1.642        |
| 1000                 | 149.579                 |    | 2.963        | 630.168   |    | 1.250        |
| 1160                 | 87.483                  |    | 3.481        | 384.163   |    | 2.525        |
| 1320                 | 22.589                  |    | 3.626        | 203.905   |    | 2.444        |
| 1400                 | 38.202                  |    | 3.508        | 188.451   |    | 3.576        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 18  
VERTICAL ANALYSIS

# CONDITION 19 VERTICAL ANALYSIS

CG ACCELERATION:  
 $\bar{A}$  .001650 g  
 $N$  2.234 PER SEC

CG 186,000 LB. SPEED  
 ALT. 15,000 FT.  $V_T$  472 KT.  
 $V_0$  375 KT.  
 CG 16.3 PERCENT MAC  $M$  .76

| WING<br>STATION | $\eta$ | BEAM BENDING MOMENT     |        |                 | BEAM SHEAR |    |                 | TORSION                 |    |                 |
|-----------------|--------|-------------------------|--------|-----------------|------------|----|-----------------|-------------------------|----|-----------------|
|                 |        | 10 <sup>3</sup> IN. LB. |        | No.<br>PER SEC. | LB.        |    | No.<br>PER SEC. | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. |
|                 |        | $\bar{A}$               | 19     |                 | $\bar{A}$  | 19 |                 | $\bar{A}$               | 19 |                 |
| 0               | 0      | 265.524                 | 17,950 | 1.506           | 851.978    |    | 1.123           | 76.982                  |    | 2.192           |
| 94.4            | .12    | 213.497                 | 13,800 | 1.333           | 653.334    |    | 2.144           | 44.620                  |    | 3.153           |
| 157.3           | .20    | 190.512                 | 10,720 | 1.152           | 601.776    |    | 2.307           | 44.922                  |    | 3.040           |
| 259.6           | .33    | 133.991                 | 7,440  | 1.162           | 529.425    |    | 2.361           | 44.911                  |    | 2.831           |
| 322.5           | .41    | 71.652                  | 5,300  | 1.095           | 442.326    |    | 1.224           | 28.390                  |    | 2.777           |
| 432.7           | .55    | 52.032                  | 2,800  | 1.355           | 328.921    |    | 1.368           | 27.706                  |    | 2.647           |
| 503.5           | .64    | 32.856                  |        | 1.576           | 227.112    |    | 1.764           | 27.930                  |    | 2.627           |
| 550.7           | .70    | 20.225                  |        | 1.725           | 175.077    |    | 1.324           | 5.386                   |    | 3.948           |
| 645.1           | .82    | 6.576                   |        | 2.659           | 81.967     |    | 1.208           | 2.600                   |    | 4.199           |
| 715.9           | .91    | 1.645                   |        | 3.728           | 39.302     |    | 2.933           | 1.208                   |    | 4.668           |

## CONDITION 19 VERTICAL ANALYSIS

| FUSELAGE<br>BODY<br>BALANCE<br>STATION | BENDING MOMENT          |    |                 | SHEAR     |    |                 |
|----------------------------------------|-------------------------|----|-----------------|-----------|----|-----------------|
|                                        | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. | LB.       |    | No.<br>PER SEC. |
|                                        | $\bar{A}$               | 19 |                 | $\bar{A}$ | 19 |                 |
| 300                                    | 21.655                  |    | 4.652           | 244.955   |    | 3.935           |
| 480                                    | 53.218                  |    | 3.448           | 533.431   |    | 2.909           |
| 620                                    | 175.946                 |    | 3.022           | 670.373   |    | 2.430           |
| 720                                    | 244.763                 |    | 2.791           | 761.426   |    | 2.130           |
| 890                                    | 231.081                 |    | 2.731           | 774.641   |    | 1.828           |
| 1000                                   | 169.991                 |    | 3.118           | 650.765   |    | 2.132           |
| 1160                                   | 101.240                 |    | 3.570           | 421.497   |    | 2.734           |
| 1320                                   | 58.571                  |    | 3.477           | 237.315   |    | 2.548           |
| 1400                                   | 42.067                  |    | 3.648           | 210.144   |    | 3.746           |
| 1636                                   | 0                       | 0  | —               | 0         | 0  | —               |

# CONDITION 20 VERTICAL ANALYSIS

GW 186,000 LB.  
 ALT. 30,000 FT.  
 CG 16.3 PERCENT MAC

SPEED:  
 V<sub>T</sub> 530 KT  
 V<sub>E</sub> 327 KT  
 M .90

CG ACCELERATION:  
 A .019130 g  
 N. 2.202 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 230.340                 | 19,300 | 1.287        | 662.219    |    | 1.483        | 102.246                 |    | 1.931        |
| 90.4         | .12    | 196.496                 | 14,600 | 1.204        | 505.191    |    | 1.300        | 60.824                  |    | 2.267        |
| 157.3        | .20    | 109.147                 | 12,000 | 1.173        | 472.620    |    | 1.338        | 54.382                  |    | 2.518        |
| 259.6        | .33    | 125.946                 | 8,300  | 1.311        | 422.337    |    | 2.010        | 53.868                  |    | 2.892        |
| 322.5        | .41    | 20.451                  | 6,000  | 1.210        | 405.731    |    | 1.316        | 26.686                  |    | 2.805        |
| 432.7        | .55    | 45.537                  | 3,190  | 1.436        | 307.803    |    | 1.325        | 25.447                  |    | 2.423        |
| 503.5        | .64    | 30.891                  |        | 1.667        | 253.766    |    | 1.563        | 25.202                  |    | 2.337        |
| 550.7        | .70    | 18.369                  |        | 1.578        | 199.016    |    | 1.354        | 5.875                   |    | 3.476        |
| 645.1        | .82    | 6.010                   |        | 2.594        | 31.474     |    | 1.665        | 3.188                   |    | 3.631        |
| 715.3        | .91    | 1.579                   |        | 3.786        | 36.790     |    | 2.559        | 1.659                   |    | 3.822        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300                  | 15.624                  |    | 5.031        | 171.185   |    | 4.278        |
| 480                  | 64.114                  |    | 3.777        | 355.324   |    | 3.116        |
| 620                  | 117.201                 |    | 3.273        | 443.277   |    | 2.527        |
| 720                  | 162.805                 |    | 2.286        | 508.775   |    | 2.153        |
| 890                  | 211.164                 |    | 2.455        | 690.535   |    | 1.531        |
| 1000                 | 142.226                 |    | 2.895        | 579.152   |    | 1.914        |
| 1160                 | 17.026                  |    | 3.424        | 372.279   |    | 2.461        |
| 1320                 | 52.005                  |    | 3.570        | 209.364   |    | 3.430        |
| 1400                 | 37.745                  |    | 3.532        | 187.008   |    | 3.710        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 20  
 VERTICAL ANALYSIS

# CONDITION 2.1 VERTICAL ANALYSIS

GW 186,000 LB.      SPEED 516 KT.      CG ACCELERATION: X .01380g  
 ALT. 40,000 FT.      V<sub>2</sub> 260 KT.      N<sub>0</sub> 1.943 PER SEC.  
 CG 16.3 PERCENT MAC      M .90

| WING STATION | WING STATION | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |              | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |              | X                       | 19     |              | X          | 19     |              | X                       | 19     |              |
| 0            | 0            | 195.4                   | 15,800 | 1.085        | 508.4      |        | 1.188        | 86.15                   |        | 1.651        |
| 94.4         | .12          | 176.9                   | 13,200 | 1.061        | 392.3      | 48,200 | 1.419        | 4550                    | -3,940 | 2.654        |
| 157.3        | .20          | 148.6                   | 9,400  | 1.067        | 372.7      | 40,000 | 1.514        | 41.26                   | -2,570 | 2.743        |
| 259.6        | .33          | 111.0                   | 7,000  | 1.175        | 343.8      | 28,600 | 1.580        | 40.00                   | -1,540 | 2.651        |
| 322.5        | .41          | 81.66                   | 3,900  | 1.34         | 349.5      | 31,200 | 1.155        | 22.35                   | -100   | 2.286        |
| 432.7        | .55          | 44.81                   | 2,500  | 1.644        | 271.8      | 19,700 | 1.179        | 21.41                   | -600   | 2.229        |
| 503.5        | .64          | 29.67                   | 1,800  | 1.526        | 227.1      | 12,100 | 1.360        | 21.19                   | -580   | 2.152        |
| 550.7        | .70          | 17.56                   | 400    | 2.149        | 148.6      | 14,400 | 1.186        | 4.533                   | -50    | 2.920        |
| 645.1        | .82          | 5.730                   | 100    | 3.077        | 77.76      | 7,000  | 1.446        | 2.472                   | -30    | 2.964        |
| 715.9        | .91          | 1.425                   |        |              | 35.28      | 2,800  | 2.053        | 1.284                   | -20    | 3.180        |

## CONDITION 2.1 VERTICAL ANALYSIS

| BOOY BALANCE STATION | BOOY BALANCE STATION | BENDING MOMENT          |       |              | SHEAR |    |              |
|----------------------|----------------------|-------------------------|-------|--------------|-------|----|--------------|
|                      |                      | 10 <sup>3</sup> IN. LB. |       | No. per sec. | LB.   |    | No. per sec. |
|                      |                      | X                       | 19    |              | X     | 19 |              |
| 300                  | 300                  | 1003                    | 4,929 | 4.188        | 110.0 |    | 4.188        |
| 480                  | 480                  | 4156                    | 3,668 | 2.923        | 237.1 |    | 2.923        |
| 620                  | 620                  | 7801                    | 3,110 | 2.260        | 3006  |    | 2.260        |
| 720                  | 720                  | 109.2                   | 2,782 | 1.855        | 361.5 |    | 1.855        |
| 890                  | 890                  | 164.1                   | 2,108 | 1.268        | 550.9 |    | 1.268        |
| 1000                 | 1000                 | 113.0                   | 2,549 | 1.505        | 460.3 |    | 1.505        |
| 1160                 | 1160                 | 64.21                   | 3,184 | 2.112        | 291.4 |    | 2.112        |
| 1320                 | 1320                 | 36.52                   | 3,416 | 3.154        | 156.5 |    | 3.154        |
| 1400                 | 1400                 | 26.71                   | 3,374 | 3.441        | 137.3 |    | 3.441        |
| 1636                 | 1636                 | 0                       | -     | -            | 0     | 0  | -            |



# CONDITION 22 VERTICAL ANALYSIS

GW 186,000 LB. ALT. 22,000 FT. CG 16.3 PERCENT MAC  
 SPEED V<sub>T</sub> 359 KT. V<sub>E</sub> 253 KT. M .59  
 CG ACCELERATION: A .013930 G N<sub>z</sub> 1.763 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |    | No. per sec. | 10 <sup>3</sup> IN. LB. |    | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 201.036                 | 17,750 | 1.117        | 533.178    |    | 1.228        | 60.697                  |    | 1.619        |
| 94.4         | .12    | 171.576                 | 14,900 | 1.012        | 415.023    |    | 1.525        | 33.026                  |    | 2.208        |
| 157.3        | .20    | 149.401                 | 11,850 | 0.954        | 373.650    |    | 1.685        | 32.476                  |    | 2.281        |
| 253.6        | .33    | 113.113                 | 9,800  | 1.044        | 333.853    |    | 1.714        | 32.921                  |    | 2.684        |
| 322.5        | .41    | 84.902                  | 6,800  | 1.006        | 353.325    |    | 1.043        | 19.382                  |    | 2.240        |
| 432.7        | .55    | 47.076                  | 3,700  | 1.195        | 375.682    |    | 1.167        | 19.124                  |    | 2.118        |
| 503.5        | .64    | 30.807                  | 2,420  | 1.384        | 227.715    |    | 1.398        | 19.423                  |    | 2.116        |
| 550.7        | .70    | 18.962                  |        | 1.363        | 158.438    |    | 1.018        | 2.966                   |    | 2.831        |
| 645.1        | .82    | 6.142                   |        | 1.862        | 83.111     |    | 1.338        | 1.613                   |    | 2.740        |
| 715.3        | .91    | 1.440                   |        | 2.517        | 37.248     |    | 1.889        | 0.741                   |    | 3.108        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. per sec. | LB.       |    | No. per sec. |
|                      | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300                  | 11.963                  |    | 4.161        | 135.045   |    | 3.633        |
| 480                  | 51.820                  |    | 3.244        | 301.651   |    | 2.731        |
| 620                  | 98.827                  |    | 2.858        | 386.140   |    | 2.233        |
| 720                  | 138.586                 |    | 2.625        | 445.156   |    | 1.902        |
| 890                  | 153.380                 |    | 2.211        | 516.073   |    | 1.276        |
| 1000                 | 106.807                 |    | 2.665        | 438.908   |    | 1.533        |
| 1160                 | 61.663                  |    | 3.216        | 268.088   |    | 2.177        |
| 1320                 | 35.374                  |    | 3.326        | 145.853   |    | 3.210        |
| 1400                 | 25.232                  |    | 3.387        | 132.666   |    | 3.341        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 22

VERTICAL ANALYSIS

# CONDITION 23 VERTICAL ANALYSIS

GW 186,000 LB. SPEED V<sub>T</sub> 425 KT. CG ACCELERATION: A .01649 g  
 ALT. 23,000 FT. V<sub>6</sub> 300 KT. N<sub>0</sub> 1.945 PER SEC.  
 CG 16.3 PERCENT MAC M .70

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |    | No. per sec. | 10 <sup>3</sup> IN. LB. |    | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 226.145                 | 13,080 | 1.216        | 672.424    |    | 1.377        | 73.260                  |    | 1.353        |
| 94.4         | .12    | 179.489                 | 13900  | 1.095        | 490.131    |    | 1.726        | 41.116                  |    | 2.922        |
| 157.3        | .20    | 163.972                 | 11620  | 1.021        | 440.152    |    | 1.864        | 40.257                  |    | 2.236        |
| 259.6        | .33    | 143.734                 | 8,400  | 1.123        | 411.082    |    | 1.919        | 40.407                  |    | 2.787        |
| 322.5        | .41    | 91.609                  | 6,150  | 1.087        | 373.673    |    | 1.519        | 22.700                  |    | 2.410        |
| 432.7        | .55    | 50.073                  | 3,250  | 1.270        | 301.634    |    | 1.235        | 22.314                  |    | 2.328        |
| 503.5        | .64    | 32.641                  | 2,250  | 1.467        | 249.924    |    | 1.507        | 22.610                  |    | 2.239        |
| 550.7        | .70    | 19.799                  |        | 1.853        | 167.181    |    | 1.116        | 3.750                   |    | 3.331        |
| 645.1        | .82    | 6.430                   |        | 2.129        | 34.337     |    | 1.479        | 1.276                   |    | 3.599        |
| 715.3        | .91    | 1.551                   |        | 2.946        | 38.693     |    | 2.255        | 0.914                   |    | 3.804        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. per sec. | LB.       |    | No. per sec. |
|                      | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300                  | 14.341                  |    | 4.438        | 162.831   |    | 3.241        |
| 480                  | 62.639                  |    | 3.336        | 346.578   |    | 2.761        |
| 620                  | 120.025                 |    | 2.887        | 472.279   |    | 2.244        |
| 720                  | 161.327                 |    | 2.635        | 545.892   |    | 1.926        |
| 890                  | 178.140                 |    | 2.230        | 602.147   |    | 1.421        |
| 1000                 | 120.941                 |    | 2.760        | 498.582   |    | 1.693        |
| 1160                 | 69.249                  |    | 3.407        | 308.016   |    | 2.288        |
| 1329                 | 40.228                  |    | 3.584        | 161.441   |    | 3.339        |
| 1400                 | 29.354                  |    | 3.556        | 142.847   |    | 3.643        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 23  
 VERTICAL ANALYSIS

# CONDITION 2.4 VERTICAL ANALYSIS

GW 186,000 LB  
 ALT. 22,000 FT.  
 CG 16.3 PERCENT MAC

SPEED 480 KT  
 V<sub>Y</sub> 340 KT  
 M .78

CG ACCELERATION:  
 X .0194Z  
 N. 2.174 PER SEC.

## WING

| WING<br>STATION | $\eta$ | BEAM BENDING MOMENT     |        |                 | BEAM SHEAR |        |                 | TORSION                 |        |                 |
|-----------------|--------|-------------------------|--------|-----------------|------------|--------|-----------------|-------------------------|--------|-----------------|
|                 |        | 10 <sup>3</sup> IN. LB. |        | No.<br>PER SEC. | LB.        |        | No.<br>PER SEC. | 10 <sup>3</sup> IN. LB. |        | No.<br>PER SEC. |
|                 |        | $\bar{X}$               | 19     |                 | $\bar{X}$  | 19     |                 | $\bar{X}$               | 19     |                 |
| 0               | 0      | 248.8                   |        | 1.397           | 760.8      |        | 1.609           | 78.09                   |        | 2.140           |
| 94.4            | .12    | 203.2                   | 13,900 | 1.242           | 584.4      | 52,800 | 2.003           | 48.39                   | -2,390 | 3.093           |
| 157.3           | .20    | 173.8                   | 11,400 | 1.116           | 542.7      | 42,000 | 2.156           | 47.89                   | -1,850 | 3.016           |
| 259.6           | .33    | 130.2                   | 8,100  | 1.201           | 468.8      | 28,000 | 2.211           | 47.10                   | -1,560 | 2.849           |
| 322.5           | .41    | 95.00                   | 5,990  | 1.108           | 422.4      | 29,000 | 1.208           | 26.36                   | -1,010 | 2.613           |
| 432.7           | .55    | 51.18                   | 3,200  | 1.349           | 318.3      | 16,200 | 1.341           | 25.82                   | -1,010 | 2.536           |
| 503.5           | .64    | 33.19                   | 2,080  | 1.561           | 267.2      | 8,500  | 1.679           | 26.07                   | -940   | 2.433           |
| 550.7           | .70    | 19.82                   | 1,200  | 1.638           | 169.7      | 11,100 | 1.241           | 46.08                   | -270   | 3.723           |
| 645.1           | .82    | 6.451                   | 410    | 2.460           | 86.16      | 5,000  | 1.673           | 2.866                   | -150   | 3.895           |
| 715.9           | .91    | 1.601                   | 10     | 3.414           | 38.60      | 100    | 2.658           | 1.112                   | -60    | 4.354           |

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT          |    |                 | SHEAR     |    |                 |
|----------------------------|-------------------------|----|-----------------|-----------|----|-----------------|
|                            | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. | LB.       |    | No.<br>PER SEC. |
|                            | $\bar{X}$               | 19 |                 | $\bar{X}$ | 19 |                 |
| 300                        | 18.88                   |    | 4.536           | 213.9     |    | 3.854           |
| 480                        | 81.58                   |    | 3.410           | 467.9     |    | 2.866           |
| 620                        | 154.3                   |    | 2.988           | 590.2     |    | 2.376           |
| 720                        | 214.9                   |    | 2.752           | 672.3     |    | 2.068           |
| 890                        | 216.5                   |    | 2.615           | 701.1     |    | 1.681           |
| 1000                       | 154.3                   |    | 3.024           | 588.0     |    | 1.973           |
| 1160                       | 91.28                   |    | 3.523           | 389.8     |    | 2.613           |
| 1320                       | 52.48                   |    | 3.671           | 213.4     |    | 3.506           |
| 1400                       | 37.89                   |    | 3.656           | 186.0     |    | 3.744           |
| 1436                       | 0                       | 0  | —               | 0         | 0  | —               |

CONDITION 2.4  
 VERTICAL ANALYSIS

# CONDITION 24C VERTICAL ANALYSIS

GW 186,000 LB. SPEED 480 KT  
ALT. 22,000 FT. V<sub>T</sub> 340 KT.  
CG 16.3 PERCENT MAC V<sub>G</sub> 340 KT.  
M .78

C3 ACCELERATION:  
A .019773 3  
N. 1,900 PER SEC.

| WING<br>STATION | η   | BEAM BENDING MOMENT     |        |                 | BEAM SHEAR |    |                 | TORSION                 |    |                 |
|-----------------|-----|-------------------------|--------|-----------------|------------|----|-----------------|-------------------------|----|-----------------|
|                 |     | 10 <sup>3</sup> IN. LB. |        | No.<br>PER SEC. | LB.        |    | No.<br>PER SEC. | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. |
|                 |     | Σ                       | 19     |                 | Σ          | 19 |                 | Σ                       | 19 |                 |
| 0               | 0   | 253.966                 | 18,200 | 1,342           | 771.998    |    | 1,482           | 80,438                  |    | 2,110           |
| 94.4            | .12 | 208.027                 | 13,400 | 1,190           | 585.099    |    | 1,899           | 51,251                  |    | 3,091           |
| 157.3           | .20 | 178.548                 | 11,050 | 1,071           | 544.696    |    | 2,076           | 50,579                  |    | 3,030           |
| 252.6           | .33 | 133.882                 | 7,750  | 1,172           | 475.075    |    | 2,168           | 42,572                  |    | 2,972           |
| 322.5           | .41 | 97.691                  | 5,600  | 1,064           | 433.564    |    | 2,156           | 25,742                  |    | 2,611           |
| 432.7           | .55 | 52.481                  | 3,000  | 1,295           | 321.958    |    | 1,289           | 25,335                  |    | 2,494           |
| 503.5           | .64 | 34.406                  |        | 1,490           | 266.489    |    | 1,638           | 25,697                  |    | 2,383           |
| 550.7           | .70 | 20.473                  |        | 1,511           | 176.474    |    | 1,163           | 4,705                   |    | 3,676           |
| 645.1           | .82 | 6.604                   |        | 2,300           | 89.069     |    | 1,540           | 2,447                   |    | 3,821           |
| 715.9           | .91 | 1.618                   |        | 3,270           | 39.492     |    | 2,493           | 1,199                   |    | 4,250           |

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT          |    |                 | SHEAR   |    |                 |
|----------------------------|-------------------------|----|-----------------|---------|----|-----------------|
|                            | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. | LB.     |    | No.<br>PER SEC. |
|                            | Σ                       | 19 |                 | Σ       | 19 |                 |
| 300                        | 20,596                  |    | 4,228           | 237,226 |    | 3,661           |
| 480                        | 80,956                  |    | 3,387           | 406,786 |    | 3,036           |
| 620                        | 140,957                 |    | 3,141           | 459,204 |    | 2,755           |
| 720                        | 188,144                 |    | 3,002           | 502,833 |    | 2,487           |
| 890                        | 187,559                 |    | 2,902           | 644,903 |    | 1,689           |
| 1000                       | 133,358                 |    | 3,242           | 532,266 |    | 2,047           |
| 1160                       | 81,632                  |    | 3,653           | 333,370 |    | 2,794           |
| 1320                       | 49,549                  |    | 3,623           | 192,282 |    | 3,647           |
| 1400                       | 36,247                  |    | 3,557           | 176,625 |    | 3,789           |
| 1636                       | 0                       | 0  | —               | 0       | 0  | —               |

CONDITION 24C

VERTICAL ANALYSIS

# CONDITION 25 VERTICAL ANALYSIS

GW 18,000 LB. ALT. 22,000 FT. CG 16.3 PERCENT MAC  
 SPEED  $V_T$  676 KT.  $V_C$  406 KT. M .96  
 CG ACCELERATION:  $\bar{A}$  .01744 g N. 2.400 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |    | No. per sec. | 10 <sup>3</sup> IN. LB. |    | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 263.251                 | 17,300 | 1.524        | 792.043    |    | 1.816        | 121.008                 |    | 1.962        |
| 94.4         | .12    | 220.577                 | 13,160 | 1.363        | 630.255    |    | 2.174        | 71.984                  |    | 2.285        |
| 157.3        | .20    | 187.372                 | 10,650 | 1.279        | 589.058    |    | 2.271        | 66.068                  |    | 2.296        |
| 259.6        | .33    | 138.313                 | 7,000  | 1.419        | 511.413    |    | 2.303        | 62.280                  |    | 2.918        |
| 322.5        | .41    | 26.624                  | 4,720  | 1.279        | 453.220    |    | 1.469        | 29.072                  |    | 2.633        |
| 432.7        | .55    | 50.425                  | 2,050  | 1.495        | 337.197    |    | 1.482        | 28.262                  |    | 2.531        |
| 503.5        | .64    | 30.357                  | 1,320  | 1.738        | 288.878    |    | 1.769        | 28.062                  |    | 2.457        |
| 550.7        | .70    | 17.985                  |        | 1.910        | 160.587    |    | 1.683        | 7.552                   |    | 3.218        |
| 645.1        | .82    | 5.784                   |        | 3.025        | 81.045     |    | 1.979        | 4.442                   |    | 4.129        |
| 715.9        | .91    | 1.671                   |        | 4.564        | 36.218     |    | 3.052        | 2.376                   |    | 4.393        |

## FUSELAGE

| BODY STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|--------------|-------------------------|----|--------------|-----------|----|--------------|
|              | 10 <sup>3</sup> IN. LB. |    | No. per sec. | LB.       |    | No. per sec. |
|              | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300          | 20.614                  |    | 5.660        | 246.797   |    | 4.308        |
| 480          | 20.775                  |    | 5.816        | 724.940   |    | 3.321        |
| 620          | 163.543                 |    | 3.400        | 578.316   |    | 2.848        |
| 720          | 220.988                 |    | 3.183        | 640.784   |    | 2.526        |
| 890          | 270.997                 |    | 2.745        | 836.631   |    | 1.832        |
| 1000         | 196.603                 |    | 3.097        | 705.131   |    | 2.178        |
| 1160         | 117.763                 |    | 3.532        | 481.749   |    | 2.798        |
| 1320         | 66.542                  |    | 3.696        | 286.213   |    | 3.516        |
| 1400         | 47.197                  | 0  | 3.680        | 255.324   | 0  | 3.769        |
| 1636         | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 25  
VERTICAL ANALYSIS

|      |        |       |         |       |
|------|--------|-------|---------|-------|
| 1400 | 47.197 | 3.680 | 255.334 | 3.769 |
| 1636 | 0      | 0     | 0       | —     |

# CONDITION 26 VERTICAL ANALYSIS

OW 221,600 LB. CG ACCELERATION:  
 ALT. 5,000 FT.  $\bar{X}$  .02066g  
 CG 21.2 PERCENT MAC  $N$  2.029 PER SEC.

SPEED  
 $V_4$  403 KT  
 $V_6$  375 KT  
 $M$  .62

## WINGS

| WING<br>STATION | $\eta$ | BEAM BENDING MOMENT     |        |                 | BEAM SHEAR |        |                 | TORSION                 |        |                 |
|-----------------|--------|-------------------------|--------|-----------------|------------|--------|-----------------|-------------------------|--------|-----------------|
|                 |        | 10 <sup>3</sup> IN. LB. |        | No.<br>per sec. | LB.        |        | No.<br>per sec. | 10 <sup>3</sup> IN. LB. |        | No.<br>per sec. |
|                 |        | $\bar{X}$               | 19     |                 | $\bar{X}$  | 19     |                 | $\bar{X}$               | 19     |                 |
| 0               | 0      | 241.2                   |        | 1,229           | 739.9      |        | 1,416           | 75.18                   |        | 1,813           |
| 94.4            | .12    | 208.5                   | 12,200 | 1,140           | 517.8      | 43,900 | 1,818           | 35.95                   | -1,600 | 2,868           |
| 157.3           | .20    | 179.7                   | 10,100 | 1,043           | 477.1      | 35,100 | 2,056           | 32.82                   | -1,450 | 2,970           |
| 259.6           | .33    | 138.4                   | 7,200  | 1,042           | 441.3      | 24,000 | 2,068           | 32.40                   | -1,100 | 2,812           |
| 322.5           | .41    | 104.7                   | 5,600  | 1,023           | 436.2      | 26,500 | 1,278           | 19.85                   | -700   | 2,471           |
| 432.7           | .55    | 92.63                   | 2,900  | 1,283           | 337.9      | 14,500 | 1,215           | 19.04                   | -680   | 2,428           |
| 503.5           | .64    | 38.77                   | 1,900  | 1,410           | 283.7      | 8,600  | 1,513           | 19.75                   | -620   | 2,277           |
| 590.7           | .70    | 25.20                   | 1,400  | 1,808           | 208.1      | 11,000 | 1,257           | 4.984                   | -220   | 2,856           |
| 645.1           | .82    | 8.52                    | 400    | 2,338           | 114.3      | 5,000  | 1,982           | 2.705                   | -160   | 3,050           |
| 715.9           | .91    | 1.678                   | 200    | 2,681           | 49.90      | 2,000  | 2,584           | 1.974                   | -90    | 3,466           |

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT          |    |                 | SHEAR     |    |                 |
|----------------------------|-------------------------|----|-----------------|-----------|----|-----------------|
|                            | 10 <sup>3</sup> IN. LB. |    | No.<br>per sec. | LB.       |    | No.<br>per sec. |
|                            | $\bar{X}$               | 19 |                 | $\bar{X}$ | 19 |                 |
| 300                        | 18.14                   |    | 4,979           | 201.8     |    | 4,150           |
| 480                        | 16.99                   |    | 3,534           | 446.6     |    | 2,878           |
| 620                        | 146.0                   |    | 3,006           | 570.0     |    | 2,268           |
| 720                        | 204.3                   | —  | 2,717           | 657.3     | —  | 1,896           |
| 820                        | 182.2                   |    | 2,661           | 670.1     |    | 1,567           |
| 1000                       | 135.5                   |    | 3,112           | 551.9     |    | 1,578           |
| 1400                       | 84.93                   |    | 3,450           | 336.8     |    | 2,686           |
| 1320                       | 54.88                   |    | 3,346           | 207.9     |    | 3,406           |
| 1400                       | 39.07                   |    | 3,299           | 206.4     |    | 3,389           |
| 1636                       | 0                       | 0  | —               | 0         | 0  | —               |

CONDITION 26  
VERTICAL ANALYSIS

# CONDITION 27 VERTICAL ANALYSIS

GW 221,600 LB.      SPEED 472 KT  
 ALT. 15,000 FT.      V 375 KT.  
 CG 21.2 PERCENT MAC      M .76  
                                  CG ACCELERATION:  
                                  X .02027g  
                                  N 2.098 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |        | No. PER SEC. | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. |
|              |        | X                       | 19     |              | X          | 19     |              | X                       | 19     |              |
| 0            | 0      | 2351                    |        | 1.186        | 716.5      |        | 1.301        | 7472                    |        | 1.817        |
| 9A4          | .12    | 198.5                   | 13,600 | 1.133        | 492.8      | 47,800 | 1.717        | 37.38                   | -1,940 | 2.818        |
| 1573         | .20    | 175.1                   | 11,200 | 1.062        | 453.3      | 41,200 | 1.911        | 34.08                   | -1,640 | 2.904        |
| 25A6         | .33    | 134.3                   | 7,800  | 1.058        | 425.7      | 27,800 | 2.003        | 33.60                   | -1,300 | 2.750        |
| 3225         | .41    | 101.1                   | 5,700  | 1.037        | 427.6      | 27,800 | 2.295        | 20.27                   | -850   | 2.435        |
| 4327         | .55    | 57.00                   | 3,000  | 1.284        | 331.2      | 15,200 | 1.215        | 19.51                   | -820   | 2.372        |
| 5035         | .64    | 36.89                   | 2,000  | 1.452        | 278.3      | 8,600  | 1.475        | 20.14                   | -750   | 2.227        |
| 5507         | .70    | 23.78                   | 1,300  | 1.837        | 194.9      | 11,100 | 1.293        | 5.96                    | -300   | 3.015        |
| 6451         | .82    | 7.547                   | 400    | 2.413        | 107.7      | 5,000  | 2.040        | 2.795                   | -160   | 3.270        |
| 7153         | .91    | 1.573                   | 100    | 2.832        | 46.68      | 1,700  | 2.747        | 1.436                   | -70    | 3.701        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR |    |              |
|----------------------|-------------------------|----|--------------|-------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.   |    | No. PER SEC. |
|                      | X                       | 19 |              | X     | 19 |              |
| 300                  | 1619                    |    | 5.509        | 181.1 |    | 4.452        |
| 480                  | 69,560                  |    | 3.683        | 410.7 |    | 2.846        |
| 620                  | 1334                    |    | 3.014        | 534.6 |    | 2.148        |
| 720                  | 1884                    |    | 2.662        | 625.4 |    | 1.752        |
| 890                  | 176.5                   |    | 2.562        | 650.9 |    | 1.498        |
| 1030                 | 123.6                   |    | 3.096        | 531.8 |    | 1.895        |
| 1160                 | 71.54                   |    | 3.587        | 316.6 |    | 2.625        |
| 1320                 | 49.41                   |    | 3.530        | 184.1 |    | 3.566        |
| 1400                 | 35.64                   | 0  | 3.459        | 182.9 | 0  | 3.664        |
| 1636                 | 0                       | 0  | —            | 0     | 0  | —            |

CONDITION 27  
 VERTICAL ANALYSIS

# CONDITION 28 VERTICAL ANALYSIS

GW 221,600 LB.      SPEED 530 KT.      CG ACCELERATION:      ALT. 30,000 FT.      V<sub>1</sub> 327 KT.      A .016709  
 CG 21.2 PERCENT MAC      M .90      N<sub>1</sub> 2.062 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |        |              | TORSION                 |        |              |
|--------------|--------|-------------------------|--------|--------------|------------|--------|--------------|-------------------------|--------|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |        | No. per sec. | 10 <sup>3</sup> IN. LB. |        | No. per sec. |
|              |        | X                       | 19     |              | X          | 19     |              | X                       | 19     |              |
| 0            | 0      | 2140                    |        | 1.130        | 582.0      |        | 1.261        | 9008                    |        | 1.363        |
| 94.4         | .12    | 1895                    | 14,300 | 1.097        | 414.2      | 48,500 | 1.555        | 35.85                   | -4,700 | 2.357        |
| 157.3        | .20    | 1667                    | 11,800 | 1.060        | 390.3      | 38,800 | 1.625        | 29.14                   | -3,500 | 2.694        |
| 259.6        | .33    | 1260                    | 8,400  | 1.051        | 379.8      | 26,800 | 1.746        | 28.76                   | -2,200 | 2.621        |
| 322.5        | .41    | 94.54                   | 6,200  | 1.049        | 393.3      | 26,400 | 1.766        | 18.95                   | -1,250 | 2.236        |
| 432.7        | .55    | 59.22                   | 3,400  | 1.247        | 315.2      | 15,100 | 1.664        | 17.85                   | -900   | 2.259        |
| 503.5        | .64    | 53.21                   | 2,200  | 1.446        | 267.6      | 9,500  | 1.333        | 17.95                   | -630   | 2.147        |
| 550.7        | .70    | 21.44                   | 1,400  | 1.740        | 178.9      | 12,900 | 1.256        | 5.98                    | -200   | 2.771        |
| 645.1        | .82    | 6.586                   | 400    | 2.258        | 96.40      | 5,400  | 1.854        | 3.150                   | -110   | 2.988        |
| 715.9        | .91    | 1.238                   | 200    | 2.774        | 41.91      | 2,300  | 2.386        | 1.755                   | -50    | 3.286        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR |    |              |
|----------------------|-------------------------|----|--------------|-------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. per sec. | LB.   |    | No. per sec. |
|                      | X                       | 19 |              | X     | 19 |              |
| 300                  | 12.27                   |    | 5.737        | 132.0 |    | 4.747        |
| 480                  | 49.20                   |    | 4.056        | 218.6 |    | 3.154        |
| 620                  | 90.89                   |    | 3.361        | 552.7 |    | 2.366        |
| 720                  | 126.2                   |    | 2.971        | 415.4 |    | 1.897        |
| 890                  | 175.7                   |    | 2.155        | 618.5 |    | 1.363        |
| 1000                 | 172.0                   |    | 2.620        | 511.3 |    | 1.630        |
| 1160                 | 72.85                   |    | 3.233        | 312.0 |    | 2.228        |
| 1320                 | 44.23                   |    | 3.409        | 175.6 |    | 3.234        |
| 1400                 | 31.35                   |    | 3.374        | 169.6 |    | 3.546        |
| 1636                 | 0                       | 0  | -            | 0     | 0  | -            |

CONDITION 28

VERTICAL ANALYSIS



# CONDITION 29 VERTICAL ANALYSIS

GW 221,600 LB. ALT. 40,000 FT. CG 21.2 PERCENT MAC  
 SPEED  $V_T$  616 KT.  $V_C$  260 KT. M .90  
 CG ACCELERATION:  $\bar{A}$  .012642 g  $N_0$  1.837 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. per sec. | LB.        |    | No. per sec. | 10 <sup>3</sup> IN. LB. |    | No. per sec. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 182.832                 | 19,060 | 1.061        | 455.480    |    | 1.194        | 77.707                  |    | 1.178        |
| 94.4         | .12    | 164.258                 | 15,000 | 1.014        | 338.823    |    | 1.473        | 47.091                  |    | 2.118        |
| 157.3        | .20    | 145.000                 | 12,820 | 0.972        | 327.445    |    | 1.872        | 20.034                  |    | 2.689        |
| 259.6        | .33    | 110.839                 | 9,320  | 0.965        | 325.434    |    | 1.563        | 20.136                  |    | 2.567        |
| 322.5        | .41    | 93.626                  | 6,900  | 0.959        | 337.930    |    | 1.144        | 14.175                  |    | 2.072        |
| 432.7        | .55    | 47.260                  | 2,900  | 1.103        | 272.373    |    | 1.091        | 13.364                  |    | 2.105        |
| 503.5        | .64    | 29.193                  | 2,650  | 1.248        | 235.271    |    | 1.234        | 12.528                  |    | 2.033        |
| 550.7        | .70    | 19.250                  |        | 1.467        | 160.777    |    | 1.023        | 4.144                   |    | 2.271        |
| 645.1        | .82    | 5.867                   |        | 1.550        | 89.363     |    | 1.551        | 2.371                   |    | 2.403        |
| 715.9        | .91    | 1.077                   |        | 2.268        | 37.438     |    | 1.907        | 1.306                   |    | 2.093        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. per sec. | LB.       |    | No. per sec. |
|                      | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300                  | 8.945                   |    | 5.182        | 271.200   |    | 4.360        |
| 480                  | 36.912                  |    | 3.796        | 206.187   |    | 3.012        |
| 620                  | 67.830                  |    | 3.206        | 265.686   |    | 2.308        |
| 720                  | 94.572                  |    | 2.862        | 313.802   |    | 1.968        |
| 890                  | 144.434                 |    | 1.921        | 497.994   |    | 1.210        |
| 1000                 | 272.386                 |    | 2.238        | 413.226   |    | 1.434        |
| 1160                 | 568.42                  |    | 2.948        | 254.486   |    | 1.252        |
| 1320                 | 32.953                  |    | 3.181        | 138.157   |    | 2.232        |
| 1400                 | 22.927                  |    | 3.180        | 128.436   |    | 3.218        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 29  
VERTICAL ANALYSIS

# CONDITION 30 VERTICAL ANALYSIS

GW 221,600 LB. SPEED 319 KT. CG ACCELERATION:  $\Delta$  .013200 g  
ALT. 15,000 FT.  $V_4$  253 KT. N. 1.734 PER SEC.  
CG 21.2 PERCENT MAC M .51

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. |
|              |        | $\bar{A}$               | 1g     |              | $\bar{A}$  | 1g |              | $\bar{A}$               | 1g |              |
| 0            | 0      | 186.554                 | 16,550 | 1.134        | 502.332    |    | 1.476        | 64.102                  |    | 1.432        |
| 94.4         | .12    | 163.043                 | 12,800 | 1.002        | 372.477    |    | 1.380        | 24.537                  |    | 2.638        |
| 157.3        | .20    | 144.947                 | 11,200 | 0.914        | 359.511    |    | 1.355        | 20.883                  |    | 2.946        |
| 259.6        | .33    | 112.546                 | 8,330  | 0.925        | 337.322    |    | 1.309        | 21.082                  |    | 2.766        |
| 322.5        | .41    | 86.721                  | 6,800  | 0.907        | 338.797    |    | 1.093        | 13.960                  |    | 2.331        |
| 432.7        | .55    | 50.166                  | 3,750  | 1.092        | 213.667    |    | 1.091        | 13.310                  |    | 2.344        |
| 503.5        | .64    | 33.246                  |        | 1.153        | 229.884    |    | 1.354        | 13.687                  |    | 2.326        |
| 550.7        | .70    | 21.326                  |        | 1.431        | 172.893    |    | 1.082        | 3.123                   |    | 1.982        |
| 645.1        | .82    | 6.768                   |        | 1.741        | 96.381     |    | 1.545        | 1.772                   |    | 1.366        |
| 715.3        | .91    | 1.396                   |        | 1.896        | 41.925     |    | 1.826        | 0.878                   |    | 2.358        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{A}$               | 1g |              | $\bar{A}$ | 1g |              |
| 300                  | 13.753                  |    | 4.017        | 142.845   |    | 3.543        |
| 480                  | 54.261                  |    | 3.231        | 308.904   |    | 2.726        |
| 620                  | 101.864                 |    | 2.202        | 385.022   |    | 2.360        |
| 720                  | 141.129                 |    | 2.713        | 435.437   |    | 2.043        |
| 830                  | 152.762                 |    | 2.416        | 485.001   |    | 1.442        |
| 1000                 | 110.829                 |    | 2.762        | 407.531   |    | 1.727        |
| 1160                 | 68.696                  |    | 3.104        | 265.308   |    | 2.373        |
| 1329                 | 40.225                  |    | 3.102        | 166.328   |    | 3.054        |
| 1400                 | 27.770                  |    | 3.109        | 155.572   |    | 3.011        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 30  
VERTICAL ANALYSIS

# CONDITION 31 VERTICAL ANALYSIS

GW 221,600 LB. ALT. 16,000 FT. CG 21.2 PERCENT MAC

SPEED  $V_T$  378 KT.  $V_L$  300 KT.  $M$  .60

CG ACCELERATION:  $\bar{A}$  .015780 9  $N$  1.914 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. |
|              |        | $\bar{A}$               | 19     |              | $\bar{A}$  | 19 |              | $\bar{A}$               | 19 |              |
| 0            | 0      | 209.347                 | 16,550 | 1.162        | 571.001    |    | 1.415        | 69.762                  |    | 1.562        |
| 94.4         | 12     | 180.321                 | 12,500 | 1.065        | 425.964    |    | 1.835        | 28.562                  |    | 2.727        |
| 157.3        | 20     | 159.871                 | 10,750 | 0.975        | 401.303    |    | 1.958        | 25.206                  |    | 2.935        |
| 252.6        | 33     | 123.644                 | 7,000  | 0.973        | 378.470    |    | 1.921        | 25.342                  |    | 2.755        |
| 322.5        | 41     | 94.591                  | 6,000  | 0.956        | 379.056    |    | 1.180        | 16.276                  |    | 2.357        |
| 432.7        | 55     | 54.419                  | 3,400  | 1.172        | 301.928    |    | 1.141        | 15.624                  |    | 2.349        |
| 503.5        | 64     | 35.141                  |        | 1.286        | 253.564    |    | 1.387        | 16.154                  |    | 2.327        |
| 550.7        | 70     | 22.920                  |        | 1.504        | 186.535    |    | 1.127        | 3.768                   |    | 2.400        |
| 645.1        | 82     | 7.303                   |        | 1.928        | 104.045    |    | 1.734        | 2.091                   |    | 2.488        |
| 715.9        | 91     | 1.509                   |        | 2.234        | 45.179     |    | 2.151        | 1.050                   |    | 2.703        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{A}$               | 19 |              | $\bar{A}$ | 19 |              |
| 300                  | 14.180                  |    | 4.488        | 158.383   |    | 3.954        |
| 480                  | 60.285                  |    | 3.393        | 346.525   |    | 2.841        |
| 620                  | 113.745                 |    | 2.966        | 437.955   |    | 2.301        |
| 720                  | 158.462                 |    | 2.713        | 501.443   |    | 1.943        |
| 830                  | 164.747                 |    | 2.466        | 530.860   |    | 1.492        |
| 1000                 | 118.189                 |    | 2.875        | 458.861   |    | 1.795        |
| 1160                 | 73.367                  |    | 3.261        | 289.267   |    | 2.456        |
| 1320                 | 44.123                  |    | 3.254        | 176.225   |    | 3.214        |
| 1400                 | 30.963                  |    | 3.236        | 167.474   |    | 3.217        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 31

VERTICAL ANALYSIS

# CONDITION 32 VERTICAL ANALYSIS

GW 221,600 LB.      SPEED      CG ACCELERATION:  
 ALT. 15,000 FT.       $V_T$  561 KT.       $\bar{A}$  .024033 g  
 CG 21.2 PERCENT MAC       $V_0$  445 KT.       $N_0$  2.402 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. |
|              |        | $\bar{X}$               | 19     |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 244.511                 | 16,550 | 1.287        | 796.928    |    | 1.429        | 103.223                 |    | 1.780        |
| 94.4         | .12    | 209.496                 | 10,780 | 1.276        | 524.232    |    | 1.758        | 51.351                  |    | 2.625        |
| 157.3        | .20    | 182.699                 | 8,450  | 1.248        | 462.860    |    | 1.964        | 46.702                  |    | 2.825        |
| 259.6        | .33    | 136.502                 | 5,050  | 1.249        | 437.749    |    | 2.144        | 44.017                  |    | 2.768        |
| 322.5        | .41    | 99.613                  | 3,150  | 1.225        | 448.818    |    | 1.546        | 25.270                  |    | 2.533        |
| 432.7        | .55    | 54.576                  | 1,350  | 1.500        | 340.241    |    | 1.372        | 23.615                  |    | 2.462        |
| 503.5        | .61    | 33.562                  |        | 1.734        | 232.377    |    | 1.587        | 23.420                  |    | 2.330        |
| 550.7        | .70    | 21.924                  |        | 2.292        | 181.411    |    | 1.620        | 2.562                   |    | 3.445        |
| 645.1        | .82    | 7.032                   |        | 3.078        | 101.474    |    | 2.476        | 4.954                   |    | 3.746        |
| 715.9        | .91    | 1.396                   |        | 9.733        | 46.187     |    | 3.362        | 2.794                   |    | 4.034        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300                  | 18.877                  |    | 6.621        | 200.133   |    | 5.382        |
| 480                  | 73.987                  |    | 4.502        | 407.656   |    | 3.435        |
| 620                  | 134.882                 |    | 3.654        | 514.934   |    | 2.535        |
| 720                  | 185.818                 |    | 3.201        | 603.698   |    | 2.030        |
| 890                  | 221.279                 |    | 2.613        | 805.829   |    | 1.630        |
| 1000                 | 156.525                 |    | 3.110        | 669.073   |    | 2.118        |
| 1160                 | 100.012                 |    | 3.648        | 399.579   |    | 2.783        |
| 1320                 | 64.522                  |    | 3.731        | 239.643   |    | 3.713        |
| 1400                 | 46.470                  |    | 3.632        | 244.081   |    | 4.097        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 32

VERTICAL ANALYSIS

# CONDITION 24A VERTICAL ANALYSIS

GW 186,000 LB. SPEED 480 KT. CG ACCELERATION: 9  
 ALT. 22,000 FT.  $\bar{A}$  .019205  
 CG 16.3 PERCENT MAC  $N$  2.202 PER SEC.

## WING

| WING<br>STATION | $\eta$ | BEAM BENDING MOMENT     |    |                 | BEAM SHEAR |    |                 | TORSION                 |    |                 |
|-----------------|--------|-------------------------|----|-----------------|------------|----|-----------------|-------------------------|----|-----------------|
|                 |        | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. | LB.        |    | No.<br>PER SEC. | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. |
|                 |        | $\bar{A}$               | 19 |                 | $\bar{A}$  | 19 |                 | $\bar{A}$               | 19 |                 |
| 0               | 0      |                         |    | 1.386           | 747.176    |    | 1.001           | 71.115                  |    | 2.147           |
| 94.4            | .12    |                         |    | 1.215           | 871.399    |    | 2.002           | 45.326                  |    | 3.071           |
| 157.3           | .20    |                         |    | 1.067           | 529.425    |    | 2.158           | 45.564                  |    | 2.156           |
| 259.6           | .33    |                         |    | 1.137           | 452.958    |    | 2.208           | 45.461                  |    | 2.780           |
| 322.5           | .41    |                         |    | 1.062           | 396.785    |    | 1.153           | 22.137                  |    | 2.623           |
| 432.7           | .55    |                         |    | 1.317           | 301.095    |    | 1.322           | 26.706                  |    | 2.491           |
| 503.5           | .64    |                         |    | 1.534           | 259.330    |    | 1.685           | 26.990                  |    | 2.385           |
| 550.7           | .70    |                         |    | 1.672           | 190.639    |    | 1.297           | 4.602                   |    | 3.702           |
| 645.1           | .82    |                         |    | 2.563           | 75.794     |    | 1.737           | 2.364                   |    | 3.925           |
| 715.9           | .91    |                         |    | 3.508           | 34.281     |    | 2.922           | 1.109                   |    | 4.338           |

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT          |    |                 | SHEAR     |    |                 |
|----------------------------|-------------------------|----|-----------------|-----------|----|-----------------|
|                            | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. | LB.       |    | No.<br>PER SEC. |
|                            | $\bar{A}$               | 19 |                 | $\bar{A}$ | 19 |                 |
| 300                        | 18.607                  |    | 4.572           | 211.050   |    | 3.863           |
| 480                        | 80.597                  |    | 3.406           | 463.631   |    | 2.841           |
| 620                        | 182.699                 |    | 2.969           | 595.979   |    | 2.343           |
| 720                        | 212.969                 |    | 2.726           | 668.218   |    | 2.034           |
| 890                        | 209.228                 |    | 2.666           | 676.822   |    | 1.688           |
| 1000                       | 150.071                 |    | 3.078           | 566.734   |    | 1.997           |
| 1160                       | 90.307                  |    | 3.649           | 367.140   |    | 2.604           |
| 1320                       | 52.740                  |    | 3.660           | 209.898   |    | 3.539           |
| 1400                       | 38.234                  |    | 3.630           | 185.168   |    | 3.755           |
| 1636                       | 0                       | 0  | —               | 0         | 0  | —               |

CONDITION 24A  
 VERTICAL ANALYSIS

# CONDITION 24B VERTICAL ANALYSIS

GW 186,000 LB. ALT. 22,000 FT. CG 16.3 PERCENT MAC  
 SPEED V<sub>T</sub> 480 KT V<sub>E</sub> 340 KT M .78  
 CG ACCELERATION:  $\bar{A}$  .019864 g N<sub>0</sub> 2.236 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |    |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|----|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |    | No. per sec. | LB.        |    | No. per sec. | 10 <sup>3</sup> IN. LB. |    | No. per sec. |
|              |        | $\bar{X}$               | 19 |              | $\bar{X}$  | 19 |              | $\bar{X}$               | 19 |              |
| 0            | 0      | 248.717                 |    | 1.456        | 775.033    |    | 1.666        | 78.300                  |    | 2.133        |
| 94.4         | .12    | 201.653                 |    | 1.285        | 598.607    |    | 2.065        | 49.899                  |    | 2.974        |
| 157.3        | .20    | 172.067                 |    | 1.134        | 557.093    |    | 2.224        | 48.979                  |    | 2.921        |
| 259.6        | .33    | 129.094                 |    | 1.203        | 490.086    |    | 2.298        | 47.054                  |    | 2.786        |
| 322.5        | .41    | 94.058                  |    | 1.094        | 417.933    |    | 1.235        | 24.443                  |    | 2.596        |
| 432.7        | .55    | 59.620                  |    | 1.338        | 310.689    |    | 1.332        | 23.852                  |    | 2.497        |
| 503.5        | .64    | 32.610                  |    | 1.516        | 258.220    |    | 1.686        | 24.094                  |    | 2.396        |
| 550.7        | .70    | 19.810                  |    | 1.476        | 169.736    |    | 1.254        | 4.683                   |    | 3.678        |
| 645.1        | .82    | 4.440                   |    | 2.513        | 86.336     |    | 1.720        | 2.424                   |    | 3.852        |
| 715.5        | .91    | 1.589                   |    | 3.479        | 38.643     |    | 2.714        | 1.125                   |    | 4.296        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. per sec. | LB.       |    | No. per sec. |
|                      | $\bar{X}$               | 19 |              | $\bar{X}$ | 19 |              |
| 300                  | 19.900                  |    | 4.423        | 225.336   |    | 3.790        |
| 480                  | 85.763                  |    | 3.381        | 498.704   |    | 2.873        |
| 620                  | 161.665                 |    | 2.989        | 611.970   |    | 2.410        |
| 720                  | 224.361                 |    | 2.747        | 693.013   |    | 2.114        |
| 890                  | 222.709                 |    | 2.653        | 708.189   |    | 1.724        |
| 1000                 | 159.969                 |    | 3.047        | 595.869   |    | 2.011        |
| 1160                 | 95.450                  |    | 3.519        | 390.925   |    | 2.645        |
| 1320                 | 54.687                  |    | 3.666        | 223.878   |    | 3.496        |
| 1400                 | 39.318                  |    | 3.655        | 194.860   |    | 3.716        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 24B  
 VERTICAL ANALYSIS

# CONDITION 24C VERTICAL ANALYSIS

GW 186,000 LB. SPEED 480 KT.  
ALT. 22,000 FT.  $V_T$  340 KT.  
CG 16.3 PERCENT MAC  $V_e$  M  
CG ACCELERATION:  $\bar{A}$  .019773 g  
N. 1.900 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT     |        |              | BEAM SHEAR |    |              | TORSION                 |    |              |
|--------------|--------|-------------------------|--------|--------------|------------|----|--------------|-------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN. LB. |        | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. |
|              |        | $\bar{A}$               | 1g     |              | $\bar{A}$  | 1g |              | $\bar{A}$               | 1g |              |
| 0            | 0      | 253.966                 | 18,200 | 1.342        | 771.998    |    | 1.482        | 20.438                  |    | 2.110        |
| 94.4         | .12    | 208.027                 | 13,400 | 1.190        | 585.099    |    | 1.399        | 51.251                  |    | 3.091        |
| 157.3        | .20    | 178.548                 | 11,090 | 1.071        | 544.696    |    | 2.076        | 50.579                  |    | 3.030        |
| 259.6        | .33    | 133.882                 | 7,750  | 1.172        | 475.075    |    | 2.168        | 49.572                  |    | 2.872        |
| 322.5        | .41    | 97.691                  | 5,600  | 1.064        | 433.566    |    | 1.156        | 25.742                  |    | 2.611        |
| 432.7        | .55    | 52.481                  | 3,000  | 1.295        | 321.958    |    | 1.289        | 25.335                  |    | 2.494        |
| 503.5        | .64    | 34.406                  |        | 1.490        | 266.489    |    | 1.638        | 25.697                  |    | 2.383        |
| 550.7        | .70    | 20.473                  |        | 1.511        | 176.474    |    | 1.163        | 4.705                   |    | 3.676        |
| 645.1        | .82    | 6.604                   |        | 2.300        | 89.069     |    | 1.540        | 2.447                   |    | 3.821        |
| 715.9        | .91    | 1.618                   |        | 3.270        | 39.492     |    | 2.492        | 1.139                   |    | 4.260        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT          |    |              | SHEAR     |    |              |
|----------------------|-------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN. LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{A}$               | 1g |              | $\bar{A}$ | 1g |              |
| 300                  | 20.596                  |    | 4.228        | 237.236   |    | 3.661        |
| 480                  | 80.956                  |    | 3.387        | 406.736   |    | 3.036        |
| 620                  | 140.957                 |    | 3.141        | 459.204   |    | 2.755        |
| 720                  | 188.144                 |    | 3.002        | 502.833   |    | 2.487        |
| 890                  | 187.559                 |    | 2.802        | 644.903   |    | 1.689        |
| 1000                 | 133.358                 |    | 3.242        | 552.266   |    | 2.047        |
| 1160                 | 81.632                  |    | 3.653        | 333.370   |    | 2.794        |
| 1320                 | 49.549                  |    | 3.623        | 192.282   |    | 3.647        |
| 1400                 | 36.247                  |    | 3.557        | 176.625   |    | 3.769        |
| 1636                 | 0                       | 0  | —            | 0         | 0  | —            |

CONDITION 24C  
VERTICAL ANALYSIS

# CONDITION 24D VERTICAL ANALYSIS

GW 186,000 LB. SPEED CG ACCELERATION:  
 ALT. 22,000 FT.  $V_1$  480 KT.  $\bar{A}$  .020410 g  
 CG 16.3 PERCENT MAC  $V_2$  340 KT.  $N_0$  2.408 PER SEC.  
 M .78

## WING

| WING<br>STATION | $\eta$ | BEAM BENDING MOMENT     |    |                 | BEAM SHEAR |    |                 | TORSION                 |    |                 |
|-----------------|--------|-------------------------|----|-----------------|------------|----|-----------------|-------------------------|----|-----------------|
|                 |        | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. | LB.        |    | No.<br>PER SEC. | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. |
|                 |        | $\bar{A}$               | 19 |                 | $\bar{A}$  | 19 |                 | $\bar{A}$               | 19 |                 |
| 0               | 0      | 278.676                 |    | 1.731           | 877.654    |    | 2.107           | 88.003                  |    | 2.235           |
| 94.4            | .12    | 221.153                 |    | 1.444           | 726.089    |    | 2.481           | 59.172                  |    | 3.098           |
| 157.3           | .20    | 185.281                 |    | 1.210           | 682.242    |    | 2.573           | 60.054                  |    | 3.036           |
| 259.6           | .33    | 140.719                 |    | 1.350           | 584.503    |    | 2.546           | 59.020                  |    | 2.896           |
| 322.5           | .41    | 101.473                 |    | 1.214           | 452.564    |    | 1.329           | 34.442                  |    | 2.804           |
| 432.7           | .55    | 55.082                  |    | 1.484           | 359.509    |    | 1.535           | 33.539                  |    | 2.721           |
| 503.5           | .64    | 35.419                  |    | 1.782           | 317.179    |    | 1.900           | 33.468                  |    | 2.644           |
| 550.7           | .70    | 20.887                  |    | 1.897           | 174.405    |    | 1.350           | 5.022                   |    | 3.632           |
| 645.1           | .82    | 7.005                   |    | 2.713           | 90.696     |    | 1.924           | 2.876                   |    | 3.797           |
| 715.9           | .91    | 1.791                   |    | 3.539           | 41.867     |    | 2.873           | 1.208                   |    | 4.166           |

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT          |    |                 | SHEAR     |    |                 | TORSION                 |    |                 |
|----------------------------|-------------------------|----|-----------------|-----------|----|-----------------|-------------------------|----|-----------------|
|                            | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. | LB.       |    | No.<br>PER SEC. | 10 <sup>3</sup> IN. LB. |    | No.<br>PER SEC. |
|                            | $\bar{A}$               | 19 |                 | $\bar{A}$ | 19 |                 | $\bar{A}$               | 19 |                 |
| 300                        | 29.129                  |    | 3.900           | 326.929   |    | 3.573           |                         |    |                 |
| 480                        | 122.513                 |    | 3.368           | 664.966   |    | 3.091           |                         |    |                 |
| 620                        | 224.007                 |    | 3.161           | 786.484   |    | 2.797           |                         |    |                 |
| 720                        | 303.656                 |    | 3.033           | 849.766   |    | 2.565           |                         |    |                 |
| 890                        | 297.911                 |    | 2.928           | 800.575   |    | 2.100           |                         |    |                 |
| 1000                       | 224.826                 |    | 3.168           | 701.617   |    | 2.383           |                         |    |                 |
| 1160                       | 139.255                 |    | 3.430           | 512.549   |    | 2.914           |                         |    |                 |
| 1320                       | 77.810                  |    | 3.532           | 323.129   |    | 3.421           |                         |    |                 |
| 1400                       | 54.851                  |    | 3.539           | 274.556   |    | 3.552           |                         |    |                 |
| 1636                       | 0                       | 0  | —               | 0         | 0  | —               |                         |    |                 |

CONDITION 24D  
 VERTICAL ANALYSIS



# CONDITION 24E VERTICAL ANALYSIS

GW 186,000 LB. ALT. 22,000 FT. CG 16.3 PERCENT MAC  
 SPEED  $V_T$  480 KT.  $V_0$  340 KT. M .78  
 CG ACCELERATION:  $\bar{A}$  .017367 g  $N_0$  2.100 PER SEC.

## WING

| WING STATION | $\eta$ | BEAM BENDING MOMENT    |    |              | BEAM SHEAR |    |              | TORSION                |    |              |
|--------------|--------|------------------------|----|--------------|------------|----|--------------|------------------------|----|--------------|
|              |        | 10 <sup>3</sup> IN LB. |    | No. PER SEC. | LB.        |    | No. PER SEC. | 10 <sup>3</sup> IN LB. |    | No. PER SEC. |
|              |        | $\bar{A}$              | 1g |              | $\bar{A}$  | 1g |              | $\bar{A}$              | 1g |              |
| 0            | 0      | 215.344                |    | 1.242        | 650.043    |    | 1.755        | 80.856                 |    | 2.424        |
| 94.4         | .12    | 178.918                |    | 1.170        | 503.443    |    | 2.031        | 50.729                 |    | 3.137        |
| 157.3        | .20    | 153.346                |    | 1.124        | 453.526    |    | 1.882        | 47.143                 |    | 3.028        |
| 253.6        | .33    | 114.248                |    | 1.213        | 379.958    |    | 1.637        | 45.626                 |    | 2.846        |
| 322.5        | .41    | 83.082                 |    | 1.162        | 374.464    |    | 1.154        | 24.706                 |    | 2.496        |
| 432.7        | .55    | 44.652                 |    | 1.371        | 285.606    |    | 1.220        | 23.641                 |    | 2.336        |
| 503.5        | .64    | 28.428                 |    | 1.548        | 243.660    |    | 1.583        | 23.656                 |    | 2.223        |
| 550.7        | .70    | 16.956                 |    | 1.495        | 146.565    |    | 1.331        | 14.368                 |    | 3.574        |
| 645.1        | .82    | 5.406                  |    | 1.881        | 74.065     |    | 1.505        | 2.234                  |    | 3.600        |
| 715.9        | .91    | 1.311                  |    | 2.583        | 32.460     |    | 1.841        | 1.030                  |    | 3.775        |

## FUSELAGE

| BODY BALANCE STATION | BENDING MOMENT         |    |              | SHEAR     |    |              |
|----------------------|------------------------|----|--------------|-----------|----|--------------|
|                      | 10 <sup>3</sup> IN LB. |    | No. PER SEC. | LB.       |    | No. PER SEC. |
|                      | $\bar{A}$              | 1g |              | $\bar{A}$ | 1g |              |
| 300                  | 19.286                 |    | 3.974        | 215.197   |    | 3.539        |
| 480                  | 80.090                 |    | 3.433        | 433.981   |    | 3.070        |
| 620                  | 145.725                |    | 3.199        | 516.733   |    | 2.627        |
| 720                  | 197.467                |    | 3.013        | 567.065   |    | 2.249        |
| 890                  | 256.505                |    | 2.987        | 633.170   |    | 2.182        |
| 1000                 | 200.883                |    | 3.185        | 566.334   |    | 2.422        |
| 1160                 | 131.005                |    | 3.317        | 441.439   |    | 3.081        |
| 1320                 | 74.513                 |    | 3.301        | 318.402   |    | 3.297        |
| 1400                 | 51.153                 |    | 3.287        | 286.404   |    | 3.312        |
| 1636                 | 0                      | 0  | —            | 0         | 0  | —            |

CONDITION 24E  
VERTICAL ANALYSIS

# CONDITION 1 LATERAL ANALYSIS

GW : 1,600 LB.      SPEED:      V<sub>Y</sub> 280. KT.  
 ALT. 5,000 FT.      V<sub>G</sub> 269. KT.  
 CG 18.6 PERCENT MAC      M .43

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820                        | 223.8                                  | 2.094            | 315.1              | 3.106            | 69.91                                  | .8880            |
| 1020                       | 164.2                                  | 1.771            | 319.0              | 2.746            | 69.86                                  | .9193            |
| 1220                       | 85.62                                  | .7905            | 366.6              | 1.725            | 69.39                                  | .9463            |
| 1335                       | 48.19                                  | .8547            | 381.2              | 1.375            | 68.30                                  | .9536            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 38.87                                  | 1.085            | 314.7              | .7474            | 5.548                                  | 1.920            |
| 104                        | 28.50                                  | 1.211            | 266.2              | .8272            | 4.143                                  | 2.193            |
| 158.                       | 16.90                                  | 1.418            | 191.7              | 1.004            | 2.497                                  | 2.904            |
| 203                        | 9.710                                  | 1.663            | 144.0              | 1.142            | 1.448                                  | 3.459            |
| 248.                       | 4.669                                  | 1.974            | 98.96              | 1.335            | .6323                                  | 3.896            |
| 284.                       | 2.080                                  | 2.228            | 58.53              | 1.477            | 1.179                                  | 4.937            |
| WL239.                     | 6.843                                  | .8483            | 421.8              | .6896            | 20.29                                  | 1.205            |

CONDITION 1  
LATERAL ANALYSIS

# CONDITION 2 LATERAL ANALYSIS

GW 178,800.LB. SPEED: 370.KT.  
ALT. 15,000.FT. V<sub>7</sub>  
CG 17.0 PERCENT MAC V<sub>8</sub> 295.KT.  
M .59

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 223.9                                  | 1.975            | 280.2              | 2.559            | 74.07                                  | 1.026            |
| 1020                       | 167.7                                  | 1.803            | 301.5              | 2.428            | 72.95                                  | 1.007            |
| 1220.                      | 86.00                                  | .9280            | 365.3              | 1.592            | 70.35                                  | .9778            |
| 1335.                      | 48.51                                  | 1.031            | 382.7              | 1.297            | 69.17                                  | .9761            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 39.27                                  | 1.078            | 318.7              | .7899            | 5.726                                  | 2.277            |
| 104.                       | 28.78                                  | 1.189            | 269.3              | .8455            | 4.288                                  | 2.576            |
| 158.                       | 17.05                                  | 1.384            | 193.5              | .9832            | 2.614                                  | 3.344            |
| 203.                       | 9.781                                  | 1.623            | 145.1              | 1.080            | 1.513                                  | 3.860            |
| 248.                       | 4.687                                  | 1.917            | 99.42              | 1.260            | .6532                                  | 4.259            |
| 284.                       | 2.174                                  | 2.491            | 58.68              | 1.369            | 1.331                                  | 5.520            |
| WL-239.                    | 69.23                                  | .8567            | 427.8              | .7524            | 20.49                                  | 1.228            |

CONDITION 2  
LATERAL ANALYSIS

# CONDITION 3 LATERAL ANALYSIS

GW 178,800.LB. SPEED: 432.KT.  
ALT. 25,000.FT.  $V_f$   
CG 170 PERCENT MAC  $V_e$  290.KT.  
M .72

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 205.8                                  | 2.055            | 251.4              | 2.700            | 69.40                                  | 1.237            |
| 1020.                      | 154.9                                  | 1.858            | 219.4              | 2.593            | 68.61                                  | 1.229            |
| 1220.                      | 77.92                                  | .9959            | 337.2              | 1.666            | 66.20                                  | 1.194            |
| 1335.                      | 44.08                                  | 1.127            | 353.5              | 1.341            | 65.15                                  | 1.197            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 37.32                                  | 1.361            | 298.6              | .9054            | 5.546                                  | 2.398            |
| 104.                       | 27.53                                  | 1.520            | 253.2              | .9988            | 4.201                                  | 2.731            |
| 158.                       | 16.81                                  | 1.786            | 183.2              | 1.214            | 2.661                                  | 3.506            |
| 203.                       | 9.633                                  | 2.094            | 138.2              | 1.355            | 1.612                                  | 3.992            |
| 248.                       | 4.720                                  | 2.447            | 95.71              | 1.611            | .7113                                  | 4.310            |
| 284.                       | 2.301                                  | 3.066            | 56.79              | 1.736            | 1.455                                  | 5.357            |
| WL239.                     | 65.14                                  | 1.016            | 400.3              | .8281            | 19.50                                  | 1.530            |

# CONDITION 3 LATERAL ANALYSIS

C-44

**CONDITION 4**  
**LATERAL ANALYSIS**

**VERTICAL TAIL**

| ELASTIC AXIS STATION |  | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------|--|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                      |  | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                   |  | 38.43                                  | 1.052            | 312.4              | .8125            | 5.679                                  | 2.201            |
| 104                  |  | 28.17                                  | 1.296            | 263.8              | .8805            | 4.272                                  | 2.521            |
| 158                  |  | 16.72                                  | 1.521            | 189.3              | 1.047            | 2.637                                  | 3.351            |
| 203                  |  | 9.632                                  | 1.794            | 141.6              | 1.167            | 1.584                                  | 4.161            |
| 248                  |  | 4.646                                  | 2.117            | 97.13              | 1.376            | .6730                                  | 4.112            |
| 284                  |  | 2.197                                  | 2.714            | 57.21              | 1.490            | 1.365                                  | 5.102            |
| WL 239               |  | 67.80                                  | .8962            | 420.3              | .7613            | 20.08                                  | 1.532            |

# CONDITION 5 LATERAL ANALYSIS

GW 191,800 LB. SPEED: 370 KT.  
ALT. 15,000 FT.  $V_7$   
CG 19.6 PERCENT MAC  $V_6$  299. KT.  
M .59

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                |                  | SHEAR              |                  | TORSION                       |                  |
|----------------------------|-------------------------------|------------------|--------------------|------------------|-------------------------------|------------------|
|                            | $\bar{A}$ ,<br>$10^3$ IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>$10^3$ IN. LB. | No.,<br>PER SEC. |
| 820                        | 246.2                         | 1.825            | 325.3              | 2.267            | 78.60                         | 1.084            |
| 1020                       | 181.8                         | 1.669            | 343.1              | 2.240            | 77.26                         | 1.077            |
| 1220                       | 92.76                         | .8342            | 397.3              | 1.498            | 74.47                         | 1.047            |
| 1335                       | 52.36                         | .9623            | 411.7              | 1.223            | 73.19                         | 1.049            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                |                  | SHEAR              |                  | TORSION                       |                  |
|----------------------------|-------------------------------|------------------|--------------------|------------------|-------------------------------|------------------|
|                            | $\bar{A}$ ,<br>$10^3$ IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>$10^3$ IN. LB. | No.,<br>PER SEC. |
| 67                         | 41.43                         | .206             | 335.3              | .7961            | 59.73                         | 2.151            |
| 104                        | 30.41                         | 1.354            | 283.5              | .8767            | 4.505                         | 2.481            |
| 188                        | 18.09                         | 1.603            | 203.6              | 1.071            | 2.796                         | 3.318            |
| 203                        | 104.6                         | 1.896            | 152.4              | 1.207            | 1.698                         | 4.107            |
| 248                        | 5.070                         | 2.238            | 104.8              | 1.446            | .7296                         | 4.097            |
| 284                        | 2.426                         | 2.849            | 61.74              | 1.563            | 1.443                         | 5.001            |
| 4123.9                     | 72.82                         | .8948            | 450.8              | .7274            | 21.74                         | 1.356            |

CONDITION 5  
LATERAL ANALYSIS

**CONDITION 6**  
**LATERAL ANALYSIS**

|      |                  |                |         |
|------|------------------|----------------|---------|
| GW   | 211,600 LB.      | SPEED:         |         |
| ALT. | 15,000 FT.       | V <sub>4</sub> | 370 KT. |
| CS   | 20.6 PERCENT MAC | V <sub>6</sub> | 295 KT. |
|      |                  | M              | .59     |

### VERTICAL TAIL

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                |                      | SHEAR                  |                      | TORSION                |                      |
|----------------------------|-------------------------------|----------------------|------------------------|----------------------|------------------------|----------------------|
|                            | $\bar{A}$ ,<br>$10^3$ IN.-LB. | $N_0$ ,<br>PER. SEC. | $\bar{A}$ ,<br>IN.-LB. | $N_0$ ,<br>PER. SEC. | $\bar{A}$ ,<br>IN.-LB. | $N_0$ ,<br>PER. SEC. |
| 820                        | 260.8                         | 1.696                | 352.3                  | 2.122                | 61.51                  | 1.047                |
| 1020                       | 190.8                         | 1.544                | 365.9                  | 2.096                | 80.00                  | 1.042                |
| 1220                       | 98.49                         | .7764                | 415.8                  | 1.390                | 77.15                  | 1.013                |
| 1335                       | 55.52                         | .8851                | 428.9                  | 1.129                | 75.79                  | 1.016                |

| ELASTIC<br>AXIS<br>STATION |  | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|--|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            |  | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         |  | 42.58                                  | 1.185            | 347.8              | .7717            | 6.076                                  | 2.104            |
| 104                        |  | 31.47                                  | 1.334            | 293.4              | .8553            | 4.584                                  | 2.442            |
| 158                        |  | 18.71                                  | 1.585            | 210.8              | 1.050            | 2.835                                  | 3.292            |
| 203                        |  | 10.81                                  | 1.877            | 157.7              | 1.190            | 1.722                                  | 4.091            |
| 248                        |  | 5.238                                  | 2.220            | 108.4              | 1.430            | .7477                                  | 4.104            |
| 284                        |  | 2.502                                  | 2.931            | 63.86              | 1.547            | 1.422                                  | 5.046            |
| W.239                      |  | 75.36                                  | .8374            | 466.6              | .7043            | 22.56                                  | .352             |

# CONDITION 7 LATERAL ANALYSIS

GW 163,800. LB. SPEED: 480. KT.  
ALT. 30,000. FT. V<sub>7</sub> 294. KT.  
CG 16.4 PERCENT MAC V<sub>6</sub> M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 213.4                                  | 2.023            | 232.8              | 2.653            | 72.04                                  | 1.353            |
| 1020.                      | 161.0                                  | 1.835            | 287.2              | 2.579            | 71.23                                  | 1.350            |
| 1220.                      | 81.36                                  | 1.076            | 349.6              | 1.662            | 68.74                                  | 1.313            |
| 1335.                      | 45.99                                  | 1.199            | 366.3              | 1.340            | 67.67                                  | 1.317            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         | 3840                                   | 1.505            | 308.6              | .9699            | 5.774                                  | 2.506            |
| 104.                       | 28.79                                  | 1.694            | 262.0              | 1.043            | 4.408                                  | 2.858            |
| 158.                       | 17.38                                  | 1.993            | 190.2              | 1.341            | 2.956                                  | 3.642            |
| 203.                       | 10.24                                  | 2.327            | 143.7              | 1.504            | 1.779                                  | 4.097            |
| 248.                       | 5.080                                  | 2.698            | 100.1              | 1.795            | .7956                                  | 4.372            |
| 284.                       | 2.546                                  | 3.304            | 59.41              | 1.932            | 1.613                                  | 5.371            |
| VL239.                     | 67.46                                  | 1.103            | 413.6              | .8658            | 20.39                                  | 1.685            |

CONDITION 7  
LATERAL ANALYSIS



# CONDITION 8 LATERAL ANALYSIS

GW 163,800 LB.      SPEED:      V<sub>4</sub> 475 KT.  
 ALT. 35,000 FT.      V<sub>6</sub> 263 KT.  
 CG 16.4 PERCENT MAC      M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN.-LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>IN.-LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 192.2                                  | 2.000                        | 226.8              | 2.594                        | 62.75                  | 1.408                        |
| 1020                       | 145.4                                  | 1.819                        | 258.4              | 2.520                        | 63.15                  | 1.336                        |
| 1220                       | 73.76                                  | 1.000                        | 317.1              | 1.643                        | 62.22                  | 1.246                        |
| 1335                       | 41.75                                  | 1.130                        | 352.8              | 1.328                        | 61.30                  | 1.243                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN.-LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN.-LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 35.32                                  | 1.415                        | 280.8              | .9081                        | 5.196                                  | 2.267                        |
| 104                        | 26.10                                  | 1.585                        | 238.5              | 1.016                        | 3.952                                  | 2.589                        |
| 158                        | 15.71                                  | 1.861                        | 173.2              | 1.264                        | 2.534                                  | 3.342                        |
| 203                        | 9.219                                  | 2.187                        | 130.9              | 1.418                        | 1.559                                  | 3.824                        |
| 248                        | 4.553                                  | 2.551                        | 91.03              | 1.694                        | .6925                                  | 4.122                        |
| 284                        | 2.193                                  | 3.070                        | 54.07              | 1.821                        | 1.396                                  | 5.048                        |
| WL239                      | 61.34                                  | 1.037                        | 357.9              | .7997                        | 18.56                                  | 1.621                        |

CONDITION 8

LATERAL ANALYSIS

# CONDITION 9 LATERAL ANALYSIS

GW 163,800 LB. SPEED: V<sub>Y</sub> 475 KT.  
ALT. 40,000 FT. V<sub>Z</sub> 234 KT.  
CG 16.4 PERCENT MAC M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR               |                              | TORSION                |                              |
|----------------------------|----------------------------------------|------------------------------|---------------------|------------------------------|------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>L.B. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 171.4                                  | 1.964                        | 201.4               | 2.516                        | 55.64                  | 1.320                        |
| 1020                       | 129.8                                  | 1.794                        | 229.3               | 2.443                        | 56.07                  | 1.256                        |
| 1220                       | 66.03                                  | .9350                        | 283.0               | 1.617                        | 55.36                  | 1.178                        |
| 1335                       | 37.39                                  | 1.073                        | 297.5               | 1.312                        | 54.54                  | 1.175                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR               |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|---------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>L.B. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 31.44                                  | 1.344                        | 250.8               | .8528                        | 4.552                                  | 1.817                        |
| 104                        | 23.21                                  | 1.507                        | 212.7               | .9595                        | 3.435                                  | 2.082                        |
| 158                        | 13.94                                  | 1.773                        | 154.2               | 1.191                        | 2.154                                  | 2.748                        |
| 203                        | 8.139                                  | 2.076                        | 116.5               | 1.340                        | 1.300                                  | 3.297                        |
| 248                        | 3.994                                  | 2.418                        | 80.80               | 1.604                        | .5669                                  | 3.627                        |
| 284                        | 1.944                                  | 3.011                        | 48.01               | 1.720                        | 1.115                                  | 4.078                        |
| WL239                      | 54.73                                  | .9770                        | 335.8               | .7404                        | 16.50                                  | 1.536                        |

CONDITION 9

LATERAL ANALYSIS

# CONDITION 10 LATERAL ANALYSIS

GW 204,000 LB.  
 ALT. 35,000 FT.  
 CG 21.5 PERCENT MAC

SPEED:  
 V<sub>Y</sub> 475 KT.  
 V<sub>E</sub> 263 KT.  
 M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | No.,<br>PER SEC. |
| 820                        | 236.3                                  | 1.738            | 315.6              | 2.161            | 73.49                  | 1.141            |
| 1020                       | 172.9                                  | 1.587            | 333.3              | 2.132            | 72.30                  | 1.139            |
| 1220                       | 88.58                                  | .8572            | 374.9              | 1.439            | 69.82                  | 1.102            |
| 1335                       | 50.13                                  | .9764            | 385.5              | 1.170            | 68.62                  | 1.105            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         | 39.18                                  | 1.288            | 313.3              | .8143            | 5.522                                  | 2.139            |
| 104                        | 28.94                                  | 1.440            | 265.4              | .9121            | 4.183                                  | 2.460            |
| 158                        | 17.33                                  | 1.702            | 192.3              | 1.136            | 2.644                                  | 3.223            |
| 203                        | 10.11                                  | 2.003            | 144.8              | 1.276            | 1.611                                  | 3.726            |
| 248                        | 4.946                                  | 2.947            | 100.3              | 1.536            | .7128                                  | 4.036            |
| 284                        | 2.405                                  | 2.950            | 59.42              | 1.651            | 1.415                                  | 5.000            |
| WL239                      | 68.25                                  | .9299            | 418.2              | .7193            | 20.72                                  | 1.464            |

CONDITION 10  
 LATERAL ANALYSIS

# CONDITION II LATERAL ANALYSIS

GW 183,000 LB.      SPEED:  
ALT. 35,000 FT.      V 475 KT.  
CG 19.4 PERCENT MAC      V 263 KT.  
M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 213.7                                  | 1.836                        | 271.2              | 2.353                        | 66.25                  | 1.361                        |
| 1020                       | 158.2                                  | 1.665                        | 294.5              | 2.296                        | 66.76                  | 1.286                        |
| 1220                       | 81.17                                  | .9145                        | 344.5              | 1.509                        | 65.99                  | 1.194                        |
| 1335                       | 45.94                                  | 1.036                        | 357.8              | 1.219                        | 64.95                  | 1.193                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 37.36                                  | 1.378                        | 296.8              | .8663                        | 5.342                                  | 2.216                        |
| 104                        | 27.61                                  | 1.548                        | 251.9              | .9754                        | 4.060                                  | 2.548                        |
| 158                        | 16.61                                  | 1.827                        | 182.9              | 1.220                        | 2.594                                  | 3.316                        |
| 203                        | 9.726                                  | 2.143                        | 138.0              | 1.374                        | 1.598                                  | 3.812                        |
| 248                        | 4.789                                  | 2.496                        | 95.95              | 1.648                        | .7121                                  | 4.111                        |
| 284                        | 2.358                                  | 3.099                        | 56.98              | 1.772                        | 1.403                                  | 5.060                        |
| VL239                      | 64.78                                  | .9956                        | 39.64              | .7607                        | 19.69                                  | 1.871                        |

CONDITION II

LATERAL ANALYSIS

# CONDITION 12 LATERAL ANALYSIS

GW 159,000 LB. SPEED: 310 KT.  
ALT. 10,000 FT.  $V_f$  264 KT.  
CG 17.0 PERCENT MAC  $V_b$  M .48

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT              |                    | SHEAR             |                     | TORSION                     |                     |
|----------------------------|-----------------------------|--------------------|-------------------|---------------------|-----------------------------|---------------------|
|                            | $\bar{A}$ ,<br>$10^3$ IN LB | $N_b$ ,<br>PER SEC | $\bar{A}$ ,<br>LB | $N_b$ ,<br>PER SEC. | $\bar{A}$ ,<br>$10^3$ IN LB | $N_b$ ,<br>PER SEC. |
| 820                        | 189.8                       | 2.036              | 225.0             | 2.473               | 63.92                       | 1.051               |
| 1020                       | 143.5                       | 1.869              | 253.9             | 2.439               | 63.09                       | 1.029               |
| 1220                       | 71.84                       | .9623              | 313.7             | 1.677               | 60.88                       | 1.001               |
| 1335                       | 40.66                       | 1.050              | 329.3             | 1.369               | 59.89                       | .963                |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT              |                     | SHEAR             |                     | TORSION                     |                     |
|----------------------------|-----------------------------|---------------------|-------------------|---------------------|-----------------------------|---------------------|
|                            | $\bar{A}$ ,<br>$10^3$ IN LB | $N_b$ ,<br>PER SEC. | $\bar{A}$ ,<br>LB | $N_b$ ,<br>PER SEC. | $\bar{A}$ ,<br>$10^3$ IN LB | $N_b$ ,<br>PER SEC. |
| 67                         | 34.14                       | 1.110               | 276.0             | .7932               | 5.084                       | 2.176               |
| 104                        | 25.05                       | 1.226               | 233.6             | .8455               | 38.21                       | 2.465               |
| 158                        | 14.87                       | 1.422               | 169.3             | .9937               | 23.60                       | 3.179               |
| 203                        | 8.555                       | 1.665               | 126.3             | 1.085               | 13.84                       | 3.679               |
| 248                        | 4.112                       | 1.958               | 86.72             | 1.274               | 6.036                       | 4.061               |
| 284                        | 1.920                       | 2.524               | 51.24             | 1.368               | 1.228                       | 5.005               |
| WL239                      | 60.04                       | .8586               | 370.0             | .7340               | 17.83                       | 1.310               |

CONDITION 12  
LATERAL ANALYSIS

# CONDITION 13 LATERAL ANALYSIS

GW 159,000 LB. SPEED: 380 KT.  
 ALT. 20,000 FT.  $V_7$  277 KT.  
 CG 17.0 PERCENT MAC  $V_6$  M .62

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 198.9                                  | 1.949            | 232.7              | 2.518            | 6846                                   | 1.110            |
| 1020.                      | 151.2                                  | 1.778            | 263.0              | 2.439            | 6760                                   | 1.094            |
| 1220.                      | 74.89                                  | .9383            | 331.3              | 1.582            | 6522                                   | 1.063            |
| 1335.                      | 43.49                                  | 1.052            | 349.7              | 1.285            | 6417                                   | 1.063            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 36.61                                  | 1.210            | 293.3              | .8234            | 5.386                                  | 2.203            |
| 104                        | 26.92                                  | 1.349            | 249.9              | .8991            | 4.058                                  | 2.511            |
| 158.                       | 16.04                                  | 1.586            | 180.2              | 1.283            | 2.524                                  | 3.261            |
| 203.                       | 9.279                                  | 1.867            | 135.5              | 1.203            | 1.500                                  | 3.771            |
| 248.                       | 4.496                                  | 2.200            | 93.31              | 1.431            | .6584                                  | 4.130            |
| 284.                       | 2.141                                  | 2.808            | 55.17              | 1.549            | 1.317                                  | 5.200            |
| WL239.                     | 64.25                                  | .9013            | 396.1              | .7567            | 19.14                                  | 1.388            |

CONDITION 13  
LATERAL ANALYSIS

# CONDITION 1 YAW DAMPER LATERAL ANALYSIS

GW 181,600. LB.      SPEED:  
ALT. 5,000. FT.      V<sub>1</sub> 290. KT.  
CG 18.6 PERCENT MAC      V<sub>0</sub> 269. KT.  
M .45

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 820                        | 174.3                                  | 2.737                        | 280.6              | 3.689                        | 45.13                                  | 1.407                        |
| 1020                       | 122.4                                  | 2.377                        | 272.7              | 3.306                        | 45.92                                  | 1.470                        |
| 1220                       | 55.23                                  | 1.259                        | 271.1              | 2.344                        | 45.82                                  | 1.515                        |
| 1335                       | 31.21                                  | 1.353                        | 268.0              | 1.951                        | 45.14                                  | 1.527                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 67                         | 25.84                                  | 1.737                        | 203.8              | 1.208                        | 3.751                                  | 2.866                        |
| 104                        | 19.22                                  | 1.923                        | 173.6              | 1.344                        | 2.863                                  | 3.226                        |
| 158                        | 11.68                                  | 2.215                        | 127.3              | 1.620                        | 1.857                                  | 4.003                        |
| 203                        | 6.932                                  | 2.527                        | 96.80              | 1.836                        | 1.172                                  | 4.417                        |
| 248                        | 3.486                                  | 2.877                        | 68.07              | 2.140                        | .5484                                  | 4.719                        |
| 284                        | 1.620                                  | 3.115                        | 40.60              | 2.313                        | 1.079                                  | 5.424                        |
| WL239                      | 44.63                                  | 1.380                        | 269.9              | 1.120                        | 13.81                                  | 1.879                        |

CONDITION 1 YD  
LATERAL ANALYSIS

|                 |                 |                |          |
|-----------------|-----------------|----------------|----------|
| GW <sup>2</sup> | 173,800. LB.    | SPEED:         |          |
| ALT.            | 15,000. FT.     | V <sub>4</sub> | 370. KT. |
| CG              | 17. PERCENT MAC | V <sub>6</sub> | 295. KT. |
|                 |                 | M              | .59      |

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                 |                  | SHEAR               |                  | TORSION                        |                  |
|----------------------------|--------------------------------|------------------|---------------------|------------------|--------------------------------|------------------|
|                            | $\bar{A}$ ,<br>$10^3$ IN. L.S. | No.,<br>PER SEC. | $\bar{A}$ ,<br>L.S. | No.,<br>PER SEC. | $\bar{A}$ ,<br>$10^3$ IN. L.S. | No.,<br>PER SEC. |
| 820.                       | 169.8                          | 2.498            | 226.8               | 3.064            | 47.83                          | 1.611            |
| 1020.                      | 124.0                          | 2.335            | 244.0               | 2.894            | 47.02                          | 1.589            |
| 1220.                      | 54.72                          | 1.483            | 260.7               | 2.137            | 45.25                          | 1.549            |
| 1335.                      | 31.38                          | 1.603            | 260.7               | 1.830            | 44.46                          | 1.549            |

CONDITION 2 YD  
LATERAL ANALYSIS

| ELASTIC<br>AXIS<br>POSITION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|-----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                             | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67.                         | 25.12                                  | 1.711                        | 200.7              | 1.288                        | 3.840                                  | 3.424                        |
| 104.                        | 18.63                                  | 1.898                        | 170.6              | 1.372                        | 2.942                                  | 3.791                        |
| 158.                        | 11.28                                  | 2.130                        | 124.4              | 1.567                        | 1.930                                  | 4.574                        |
| 203.                        | 6.663                                  | 2.429                        | 93.95              | 1.712                        | 1.197                                  | 4.943                        |
| 248.                        | 3.318                                  | 2.763                        | 65.46              | 1.962                        | .5446                                  | 5.179                        |
| 284.                        | 1.671                                  | 3.311                        | 38.68              | 2.124                        | 1.218                                  | 6.053                        |
| WLF 39.                     | 43.80                                  | 1.391                        | 2659               | 1.244                        | 13.57                                  | 1.885                        |



# CONDITION 3 YAW DAMPER LATERAL ANALYSIS

GW 178800 LB.      SPEED:      V<sub>y</sub> 432. KT.  
 ALT. 25,000. FT.      V<sub>z</sub> 290. KT.  
 CG 17. PERCENT MAC      M .72

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 156.9                                  | 2.513            | 208.6              | 3.080            | 44.14                                  | 1.946            |
| 1020.                      | 114.2                                  | 2.339            | 231.0              | 2.947            | 43.52                                  | 1.944            |
| 1220.                      | 48.42                                  | 1.622            | 238.8              | 2.191            | 41.85                                  | 1.898            |
| 1335                       | 28.01                                  | 1.768            | 235.8              | 1.874            | 41.17                                  | 1.905            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 23.41                                  | 2.178            | 181.9              | 1.500            | 3.648                                  | 1.670            |
| 104.                       | 17.66                                  | 2.384            | 156.0              | 1.640            | 2.865                                  | 3.636            |
| 158.                       | 11.00                                  | 1.973            | 116.0              | 1.940            | 2.005                                  | 4.001            |
| 203.                       | 6.724                                  | 3.027            | 88.75              | 2.137            | 1.322                                  | 4.656            |
| 248.                       | 3.479                                  | 3.353            | 63.33              | 2.463            | .6150                                  | 4.882            |
| 284.                       | 1.873                                  | 3.805            | 37.72              | 2.643            | 1.332                                  | 5.010            |
| WL239.                     | 40.05                                  | 1.670            | 238.6              | 1.404            | 1.242                                  | 2.302            |

CONDITION 3 YD  
LATERAL ANALYSIS

# CONDITION 4 YAW DAMPER LATERAL ANALYSIS

GW 166,600 LB. SPEED:  
ALT. 15,000 FT. V 370 KT.  
CS 18.1 PERCENT MAC V 290 KT.  
M .59

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 166.4                                  | 2.417                        | 216.6              | 2.963                        | 47.55                                  | 1.653                        |
| 1020                       | 122.2                                  | 2.258                        | 238.0              | 2.825                        | 46.77                                  | 1.633                        |
| 1220                       | 53.38                                  | 1.497                        | 257.4              | 2.080                        | 44.97                                  | 1.595                        |
| 1335                       | 30.66                                  | 1.618                        | 257.9              | 1.779                        | 44.20                                  | 1.597                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 25.08                                  | 1.794                        | 198.9              | 1.297                        | 3.852                                  | 3.243                        |
| 104                        | 18.65                                  | 1.970                        | 169.1              | 1.397                        | 2.973                                  | 3.624                        |
| 158                        | 11.37                                  | 2.257                        | 123.6              | 1.627                        | 1.991                                  | 4.442                        |
| 203                        | 6.775                                  | 2.573                        | 93.40              | 1.796                        | 1.296                                  | 5.099                        |
| 248                        | 3.414                                  | 2.909                        | 65.42              | 2.077                        | .5730                                  | 4.852                        |
| 284                        | 1.758                                  | 3.427                        | 38.73              | 2.229                        | 1.252                                  | 5.537                        |
| WL239                      | 43.43                                  | 1.421                        | 263.9              | 1.235                        | 13.57                                  | 1.983                        |

CONDITION 4 YD

LATERAL ANALYSIS

# CONDITION 5 YAW DAMPER LATERAL ANALYSIS

GW 191,800 LB.      SPEED:      V<sub>4</sub> 370 KT.  
 ALT. 15,000 FT.      V<sub>6</sub> 295 KT.  
 CG 19% PERCENT MAC      M .59

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 820                        | 179.8                                  | 2.327                        | 253.6              | 2.824                        | 49.37                                  | 1.754                        |
| 1020                       | 129.3                                  | 2.159                        | 268.5              | 2.736                        | 48.46                                  | 1.762                        |
| 1220                       | 56.32                                  | 1.351                        | 273.5              | 2.020                        | 46.58                                  | 1.721                        |
| 1335                       | 32.36                                  | 1.478                        | 269.8              | 1.720                        | 45.77                                  | 1.729                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 67                         | 26.29                                  | 1.985                        | 203.7              | 1.347                        | 3882                                   | 3.279                        |
| 104                        | 19.69                                  | 2.195                        | 173.6              | 1.487                        | 3.030                                  | 3.681                        |
| 158                        | 12.14                                  | 2.523                        | 127.8              | 1.792                        | 2.082                                  | 4.478                        |
| 203                        | 7.348                                  | 2.860                        | 97.16              | 2.006                        | 1.397                                  | 5.055                        |
| 248                        | 3.766                                  | 3.198                        | 68.91              | 2.337                        | .6354                                  | 4.832                        |
| 284                        | 1.994                                  | 3.681                        | 41.09              | 2.501                        | 1.310                                  | 5.460                        |
| WL 239                     | 44.61                                  | 1.521                        | 269.3              | 1.242                        | 14.18                                  | 2.158                        |

CONDITION 5 YD  
LATERAL ANALYSIS

# CONDITION 6 YAW DAMPER LATERAL ANALYSIS

GW 211,600 LB.      SPEED:      370 KT.  
ALT. 15,000 FT.      V<sub>Y</sub>      295 KT.  
CG 20.6 PERCENT MAC      V<sub>Z</sub>      M .59

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 188.0                                  | 2.238                        | 270.1              | 2.656                        | 49.89                                  | 1.703                        |
| 1020                       | 133.9                                  | 2.087                        | 282.2              | 2.605                        | 48.87                                  | 1.700                        |
| 1220                       | 58.57                                  | 1.306                        | 281.7              | 1.951                        | 46.99                                  | 1.660                        |
| 1335                       | 33.69                                  | 1.441                        | 276.3              | 1.669                        | 46.15                                  | 1.667                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 26.51                                  | 1.909                        | 205.5              | 1.313                        | 3.882                                  | 3.277                        |
| 104                        | 19.81                                  | 2.111                        | 174.8              | 1.444                        | 3.026                                  | 3.676                        |
| 158                        | 12.17                                  | 2.430                        | 128.4              | 1.732                        | 2.073                                  | 4.476                        |
| 203                        | 7.330                                  | 2.763                        | 97.38              | 1.936                        | 1.388                                  | 5.057                        |
| 248                        | 3.740                                  | 3.102                        | 68.86              | 2.256                        | .6331                                  | 4.832                        |
| 284                        | 1.965                                  | 3.597                        | 41.01              | 2.414                        | 1.306                                  | 5.445                        |
| WL239                      | 44.96                                  | 1.475                        | 271.8              | 1.217                        | 14.34                                  | 2.123                        |

CONDITION 6 YD  
LATERAL ANALYSIS

# CONDITION 7 YAW DAMPER LATERAL ANALYSIS

GW 163800. LB.      SPEED:      480. KT.  
ALT. 30,000. FT.      V<sub>r</sub>      294. KT.  
CS 16.4 PERCENT MAC      V<sub>s</sub>      M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820.                       | 157.1                                  | 2.527                        | 201.9              | 3.126                        | 45.12                                  | 2.141                        |
| 1020                       | 114.9                                  | 2.351                        | 229.7              | 3.020                        | 44.54                                  | 2.146                        |
| 1220                       | 48.86                                  | 1.798                        | 240.1              | 2.225                        | 42.79                                  | 2.100                        |
| 1335                       | 28.26                                  | 1.931                        | 237.0              | 1.903                        | 42.11                                  | 2.109                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 24.33                                  | 2.405                        | 183.1              | 1.635                        | 3.766                                  | 3.811                        |
| 104                        | 18.51                                  | 2.624                        | 157.8              | 1.809                        | 3.006                                  | 4.164                        |
| 158                        | 11.71                                  | 2.949                        | 118.7              | 2.152                        | 2.179                                  | 4.746                        |
| 203                        | 7.280                                  | 3.265                        | 91.47              | 2.367                        | 1.483                                  | 4.893                        |
| 248                        | 3.834                                  | 3.566                        | 66.28              | 2.713                        | .6968                                  | 4.975                        |
| 284                        | 2.120                                  | 3.959                        | 39.72              | 2.892                        | 1.477                                  | 5.812                        |
| WL239                      | 40.62                                  | 1.863                        | 239.4              | 1.503                        | 1.343                                  | 2.546                        |

CONDITION 7 YD  
LATERAL ANALYSIS

# CONDITION 8 YAW DAMPER LATERAL ANALYSIS

GW 163,800 LB.      SPEED:      V<sub>1</sub> 475 KT.  
ALT. 35,000. FT.      V<sub>2</sub> 263 KT.  
CS 16.4 PERCENT MAC      M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR                              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|------------------------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820.                       | 142.3                                  | 2.487                        | 184.0                              | 3.003                        | 38.89                                  | 2.281                        |
| 1020                       | 103.8                                  | 2.335                        | 209.5                              | 2.909                        | 38.66                                  | 2.185                        |
| 1220.                      | 43.96                                  | 1.689                        | 216.7                              | 2.212                        | 37.66                                  | 2.053                        |
| 1335                       | 25.51                                  | 1.832                        | 212.7                              | 1.910                        | 37.08                                  | 2.048                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR                              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|------------------------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 21.03                                  | 2.365                        | 162.0                              | 1.575                        | 3.241                                  | 3.595                        |
| 104                        | 15.99                                  | 2.577                        | 139.7                              | 1.740                        | 2.580                                  | 3.941                        |
| 158                        | 10.09                                  | 2.893                        | 105.2                              | 2.083                        | 1.863                                  | 4.520                        |
| 203                        | 6.265                                  | 3.213                        | 81.04                              | 2.296                        | 1.264                                  | 4.702                        |
| 248                        | 3.296                                  | 3.521                        | 58.55                              | 2.690                        | .5939                                  | 4.799                        |
| 284                        | 1.742                                  | 3.864                        | 34.95                              | 2.824                        | 1.261                                  | 5.532                        |
| WL239                      | 35.85                                  | 1.777                        | 210.2                              | 1.437                        | 1.201                                  | 2.491                        |

CONDITION 8 YD

LATERAL ANALYSIS

# CONDITION 9 YAW DAMPER LATERAL ANALYSIS

GW 163,800 LB.  
ALT. 40,000 FT.  
CG 16.4 PERCENT MAC

SPEED:  
V<sub>1</sub> 475 KT.  
V<sub>2</sub> 234 KT.  
M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 129.9                                  | 2.383                        | 170.7              | 2.781                        | 34.26                                  | 2.147                        |
| 1020                       | 94.13                                  | 2.263                        | 192.2              | 2.720                        | 33.98                                  | 2.068                        |
| 1220                       | 40.35                                  | 1.537                        | 195.9              | 2.146                        | 33.15                                  | 1.953                        |
| 1335                       | 23.44                                  | 1.687                        | 191.3              | 1.872                        | 32.62                                  | 1.950                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 18.00                                  | 2.329                        | 143.2              | 1.487                        | 2.679                                  | 3.051                        |
| 104                        | 13.68                                  | 2.541                        | 123.4              | 1.644                        | 2.108                                  | 3.359                        |
| 158                        | 8.615                                  | 2.855                        | 92.83              | 1.976                        | 1.489                                  | 3.940                        |
| 203                        | 5.320                                  | 3.165                        | 71.24              | 2.191                        | 1.002                                  | 4.255                        |
| 248                        | 2.781                                  | 3.463                        | 51.15              | 2.534                        | .4654                                  | 4.401                        |
| 284                        | 1.507                                  | 3.875                        | 30.36              | 2.721                        | .9732                                  | 4.581                        |
| WL239                      | 31.57                                  | 1.691                        | 184.6              | 1.348                        | 1.062                                  | 2.365                        |

CONDITION 9 YD

LATERAL ANALYSIS

# CONDITION 10 YAW DAMPER LATERAL ANALYSIS

GW 204,000 LB.      SPEED:      V<sub>7</sub> 475 KT.  
ALT. 35,000 FT.      V<sub>6</sub> 263 KT.  
CG 21.5 PERCENT MAC      M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR               |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|---------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>L.B. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820                        | 163.2                                  | 2.319            | 236.2               | 2.700            | 41.07                                  | 2.008            |
| 1020                       | 115.2                                  | 2.186            | 250.5               | 2.643            | 40.24                                  | 2.009            |
| 1220                       | 47.74                                  | 1.566            | 238.9               | 2.078            | 38.66                                  | 1.969            |
| 1335                       | 27.83                                  | 1.710            | 228.9               | 1.770            | 37.98                                  | 1.974            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR               |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|---------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>L.B. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         | 21.71                                  | 2.293            | 164.8               | 1.534            | 3.227                                  | 3.622            |
| 104                        | 16.48                                  | 2.505            | 141.7               | 1.698            | 2.572                                  | 3.967            |
| 158                        | 10.37                                  | 2.824            | 106.6               | 2.038            | 1.864                                  | 4.535            |
| 203                        | 6.413                                  | 3.136            | 81.83               | 2.249            | 1.267                                  | 4.708            |
| 248                        | 3.356                                  | 3.438            | 59.11               | 2.590            | .5962                                  | 4.798            |
| 284                        | 1.837                                  | 3.840            | 35.32               | 2.765            | 1.285                                  | 5.446            |
| WL239                      | 36.41                                  | 1.732            | 213.9               | 1.398            | 12.28                                  | 2.443            |

CONDITION 10 YD

LATERAL ANALYSIS



# CONDITION 11 YAW DAMPER LATERAL ANALYSIS

GW 183,000 LB.      SPEED:      V<sub>1</sub> 475 KT.  
ALT. 35,000 FT.      V<sub>2</sub> 263 KT.  
CG 19.4 PERCENT MAC      M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 151.8                                  | 2.386                        | 210.8              | 2.850                        | 39.23                                  | 2.288                        |
| 1020                       | 108.6                                  | 2.235                        | 229.2              | 2.767                        | 39.12                                  | 2.189                        |
| 1220                       | 45.81                                  | 1.613                        | 226.3              | 2.124                        | 38.19                                  | 2.048                        |
| 1335                       | 26.64                                  | 1.753                        | 219.5              | 1.837                        | 37.57                                  | 2.015                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 21.52                                  | 2.368                        | 163.3              | 1.568                        | 3.222                                  | 3.634                        |
| 104                        | 16.38                                  | 2.585                        | 140.7              | 1.740                        | 2.575                                  | 3.981                        |
| 158                        | 10.36                                  | 2.906                        | 106.2              | 2.093                        | 1.874                                  | 4.550                        |
| 203                        | 6.428                                  | 3.218                        | 81.75              | 2.312                        | 1.281                                  | 4.117                        |
| 248                        | 3.377                                  | 3.514                        | 59.23              | 2.658                        | .6052                                  | 4.803                        |
| 284                        | 1.860                                  | 3.902                        | 35.44              | 2.836                        | 1.274                                  | 5.510                        |
| WL239                      | 36.14                                  | 1.779                        | 211.7              | 1.473                        | 1.222                                  | 2.509                        |

CONDITION 11 Y. D.

LATERAL ANALYSIS

# CONDITION 12 YAW DAMPER LATERAL ANALYSIS

GW 159,000 LB.      SPEED:      310. KT.  
ALT. 10,000. FT.       $V_f$   
CG 17.0 PERCENT MAC       $V_g$  264. KT.  
M .48

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                     | SHEAR              |                     | TORSION                                |                     |
|----------------------------|----------------------------------------|---------------------|--------------------|---------------------|----------------------------------------|---------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | $N_b$ ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | $N_b$ ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | $N_b$ ,<br>PER SEC. |
| 820.                       | 151.2                                  | 2.429               | 190.3              | 2.787               | 44.10                                  | 1.513               |
| 1020.                      | 111.6                                  | 2.283               | 214.6              | 2.747               | 43.43                                  | 1.499               |
| 1220.                      | 48.72                                  | 1.434               | 237.0              | 2.112               | 41.84                                  | 1.454               |
| 1335                       | 27.98                                  | 1.521               | 238.5              | 1.804               | 41.12                                  | 1.450               |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                     | SHEAR              |                     | TORSION                                |                     |
|----------------------------|----------------------------------------|---------------------|--------------------|---------------------|----------------------------------------|---------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | $N_b$ ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | $N_b$ ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | $N_b$ ,<br>PER SEC. |
| 67.                        | 23.59                                  | 1.596               | 185.8              | 1.194               | 3.602                                  | 3.048               |
| 104.                       | 17.49                                  | 1.743               | 179.1              | 1.066               | 2.758                                  | 3.390               |
| 158.                       | 10.57                                  | 1.986               | 115.3              | 1.460               | 1.809                                  | 4.111               |
| 203.                       | 6.233                                  | 2.268               | 87.11              | 1.583               | 1.122                                  | 4.498               |
| 248.                       | 3.095                                  | 2.581               | 60.74              | 1.823               | .5114                                  | 4.753               |
| 284.                       | 1.546                                  | 3.107               | 36.03              | 1.946               | 1.121                                  | 5.419               |
| WL 239.                    | 40.60                                  | 1.285               | 280.5              | .9304               | 14.05                                  | 1.617               |

CONDITION 12.Y.D.

LATERAL ANALYSIS

# CONDITION 13 YAW DAMPER LATERAL ANALYSIS

GW 159,000. LB.      SPEED:      380. KT.  
ALT. 20,000. FT.      V<sub>y</sub>      277. KT.  
CG 17.0 PERCENT MAC      M      .62

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 820                        | 151.3                                  | 2.426                        | 190.3              | 2.950                        | 43.88                                  | 1.730                        |
| 1020                       | 111.8                                  | 2.274                        | 215.9              | 2.836                        | 43.23                                  | 1.711                        |
| 1220                       | 48.62                                  | 1.505                        | 235.5              | 2.108                        | 41.62                                  | 1.670                        |
| 1335                       | 28.04                                  | 1.631                        | 236.0              | 1.808                        | 40.93                                  | 1.673                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>o</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>o</sub> ,<br>PER SEC. |
| 67                         | 23.21                                  | 1.909                        | 183.3              | 1.342                        | 3.559                                  | 3.321                        |
| 104                        | 17.35                                  | 2.094                        | 156.5              | 1.453                        | 2.762                                  | 3.679                        |
| 158                        | 10.66                                  | 2.391                        | 115.4              | 1.708                        | 1.874                                  | 4.380                        |
| 203                        | 6.403                                  | 2.711                        | 87.69              | 1.880                        | 1.206                                  | 4.687                        |
| 248                        | 3.251                                  | 3.049                        | 61.83              | 2.176                        | .5587                                  | 4.867                        |
| 284                        | 1.696                                  | 3.556                        | 36.68              | 2.345                        | 1.201                                  | 5.663                        |
| ML239                      | 40.16                                  | 1.477                        | 241.4              | 1.261                        | 12.76                                  | 2.083                        |

CONDITION 13 YD  
LATERAL ANALYSIS

# CONDITION 1B YAW DAMPER LATERAL ANALYSIS

GW 214,400 LB.      SPEED:      V<sub>4</sub> 516. KT.  
ALT. 43,000 FT.      V<sub>6</sub> 239. KT.  
CG 21.4 PERCENT MAC      M .9

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 820.                       | 163.9                                  | 2.371                        | 240.1              | 2.705                        | 37.87                                  | 2.260                        |
| 1020.                      | 115.1                                  | 2.249                        | 252.7              | 2.659                        | 37.77                                  | 2.144                        |
| 1220.                      | 47.03                                  | 1.571                        | 237.7              | 2.140                        | 37.11                                  | 2.040                        |
| 1335.                      | 27.48                                  | 1.728                        | 226.2              | 1.878                        | 36.49                                  | 1.986                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 67.                        | 20.88                                  | 2.301                        | 158.9              | 1.510                        | 3.041                                  | 3.483                        |
| 104.                       | 15.82                                  | 2.519                        | 136.4              | 1.679                        | 2.412                                  | 3.837                        |
| 158.                       | 9.914                                  | 2.846                        | 102.5              | 2.034                        | 1.738                                  | 4.436                        |
| 203.                       | 6.104                                  | 3.173                        | 78.53              | 2.250                        | 1.173                                  | 4.664                        |
| 248.                       | 3.179                                  | 3.490                        | 56.61              | 2.602                        | .5446                                  | 4.788                        |
| 284.                       | 1.727                                  | 3.920                        | 33.82              | 2.775                        | 1.212                                  | 5.293                        |
| WL239.                     | 35.05                                  | 1.714                        | 205.9              | 1.347                        | 11.83                                  | 2.454                        |

CONDITION 1B.Y.D.  
LATERAL ANALYSIS

CONDITION 2B YAW DAMPER  
LATERAL ANALYSIS

GW 214,100 LB.      SPEED:  
ALT. 35,000 FT.      V<sub>r</sub> 519 KT.  
CG 21.4 PERCENT MAC      V<sub>e</sub> 289 KT.  
M .90

FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>b</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>s</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>t</sub> ,<br>PER SEC. |
| 82.0                       | 185.8                                  | 2.4507                       | 273.9              | 2.8578                       | 44.50                                  | 2.5092                       |
| 102.0                      | 130.7                                  | 2.3055                       | 286.9              | 2.8019                       | 44.33                                  | 2.3727                       |
| 122.0                      | 53.91                                  | 1.7714                       | 271.3              | 2.1883                       | 43.38                                  | 2.1901                       |
| 133.5                      | 31.30                                  | 1.9118                       | 259.4              | 1.9108                       | 42.66                                  | 2.1871                       |

VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>b</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>s</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>t</sub> ,<br>PER SEC. |
| 67                         | 24.77                                  | 2.4766                       | 184.8              | 1.6808                       | 3.544                                  | 3.3505                       |
| 104                        | 18.80                                  | 2.7145                       | 158.3              | 1.8629                       | 2.797                                  | 3.6547                       |
| 158                        | 11.86                                  | 3.0663                       | 118.5              | 2.2403                       | 1.992                                  | 4.2311                       |
| 203                        | 7.370                                  | 3.4039                       | 90.92              | 2.4933                       | 1.370                                  | 4.5675                       |
| 248                        | 3.889                                  | 3.7165                       | 65.96              | 2.8716                       | .6475                                  | 4.6927                       |
| 284                        | 2.154                                  | 4.1188                       | 39.66              | 3.0503                       | 1.283                                  | 4.4137                       |
| WL239                      | 40.79                                  | 1.9047                       | 242.3              | 1.5439                       | 13.71                                  | 2.6927                       |

CONDITION 2BYD

LATERAL ANALYSIS

# CONDITION 3B YAW DAMPER LATERAL ANALYSIS

GW 214,400.LB. SPEED: 528 KT.  
ALT. 50500FT.  $V_f$  320.KT.  
CG 2.14 PERCENT MAC  $V_e$  M .9

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 213.5                                  | 2.456            | 319.5              | 2.933            | 54.98                                  | 2.266            |
| 1020.                      | 149.8                                  | 2.286            | 330.3              | 2.861            | 53.86                                  | 2.272            |
| 1220.                      | 63.62                                  | 1.831            | 312.1              | 2.162            | 51.61                                  | 2.222            |
| 1335.                      | 36.69                                  | 1.943            | 299.6              | 1.866            | 50.72                                  | 2.236            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 29.59                                  | 2.509            | 218.5              | 1.767            | 4.497                                  | 4.359            |
| 104.                       | 22.46                                  | 2.738            | 187.5              | 1.946            | 3.618                                  | 4.727            |
| 158.                       | 14.17                                  | 3.082            | 140.6              | 2.307            | 2.667                                  | 5.301            |
| 203.                       | 8.801                                  | 3.418            | 107.9              | 2.534            | 1.837                                  | 5.385            |
| 248.                       | 4.635                                  | 3.738            | 78.29              | 2.935            | .8771                                  | 5.424            |
| 284.                       | 2.570                                  | 4.165            | 46.94              | 3.078            | 1.848                                  | 6.356            |
| WL239.                     | 48.35                                  | 1.975            | 286.7              | 1.644            | 16.19                                  | 2.754            |

CONDITION 3B Y.D

LATERAL ANALYSIS

# CONDITION 4B YD LATERAL ANALYSIS

GW 214,100 LB.      SPEED:      V<sub>1</sub> 544 KT.  
 ALT. 23,500 FT.      V<sub>6</sub> 374 KT.  
 CG 21.4 PERCENT MAC      M .9

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>b</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>b</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>b</sub> ,<br>PER SEC. |
| 820.                       | 270.0                                  | 2.240                        | 397.9              | 2.807                        | 76.75                                  | 1.932                        |
| 1020.                      | 192.4                                  | 2.046                        | 406.8              | 2.725                        | 75.18                                  | 1.936                        |
| 1220.                      | 89.31                                  | 1.614                        | 408.8              | 1.893                        | 72.01                                  | 1.893                        |
| 1335.                      | 50.65                                  | 1.677                        | 405.7              | 1.604                        | 70.74                                  | 1.906                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>b</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>b</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>b</sub> ,<br>PER SEC. |
| 67.                        | 39.05                                  | 2.146                        | 314.0              | 1.579                        | 6.034                                  | 4.434                        |
| 104.                       | 29.13                                  | 2.350                        | 266.2              | 1.699                        | 4.742                                  | 4.883                        |
| 158.                       | 17.90                                  | 2.687                        | 193.8              | 1.953                        | 3.292                                  | 5.730                        |
| 203.                       | 10.81                                  | 3.049                        | 145.7              | 2.143                        | 2.179                                  | 5.901                        |
| 248.                       | 5.533                                  | 3.431                        | 102.2              | 2.468                        | 1.035                                  | 5.972                        |
| 284.                       | 2.962                                  | 3.986                        | 59.93              | 2.691                        | 2.180                                  | 7.348                        |
| WL239.                     | 68.35                                  | 1.718                        | 417.4              | 1.541                        | 21.47                                  | 2.319                        |

CONDITION 4B YD  
LATERAL ANALYSIS

# CONDITION 5B YAW DAMPER LATERAL ANALYSIS

GW 214,400 LB. ALT. 18,000 FT. CS 21.4 PERCENT MAC M .8  
SPEED: V<sub>r</sub> 495 KT. V<sub>0</sub> 374 KT.

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 260.6                                  | 2.275            | 375.7              | 2.808            | 69.40                                  | 2.220            |
| 1020.                      | 185.4                                  | 2.100            | 392.8              | 2.719            | 69.05                                  | 2.093            |
| 1220.                      | 85.23                                  | 1.635            | 391.6              | 1.955            | 67.52                                  | 1.924            |
| 1335.                      | 48.54                                  | 1.702            | 385.5              | 1.675            | 66.33                                  | 1.919            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 36.10                                  | 2.175            | 294.9              | 1.568            | 5.709                                  | 4.375            |
| 104.                       | 26.96                                  | 2.380            | 250.7              | 1.682            | 4.495                                  | 4.806            |
| 158.                       | 16.57                                  | 2.715            | 183.4              | 1.930            | 3.131                                  | 5.602            |
| 203.                       | 10.00                                  | 3.077            | 138.2              | 2.119            | 2.068                                  | 5.783            |
| 248.                       | 5.116                                  | 3.459            | 96.85              | 2.442            | .9852                                  | 5.868            |
| 284.                       | 2.736                                  | 4.003            | 56.62              | 2.672            | .2067                                  | 7.133            |
| WL239.                     | 64.23                                  | 1.708            | 388.9              | 1.536            | .2039                                  | 2.296            |

CONDITION 5B Y.D.

LATERAL ANALYSIS



# CONDITION 6B YAW DAMPER LATERAL ANALYSIS

GW 214,400. LB. ALT. 15,000. FT. CG 21.4 PERCENT MAC

SPEED: V<sub>1</sub> 472.7 KT. V<sub>0</sub> 375. KT. M .76

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 820.                       | 214.6                                  | 2.214                        | 309.2              | 2.657                        | 56.22                                  | 2.127                        |
| 1020.                      | 152.7                                  | 2.058                        | 322.1              | 2.624                        | 56.06                                  | 2.004                        |
| 1220.                      | 69.69                                  | 1.566                        | 322.4              | 1.922                        | 54.97                                  | 1.843                        |
| 1335.                      | 39.83                                  | 1.647                        | 317.3              | 1.657                        | 54.01                                  | 1.839                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 67.                        | 30.12                                  | 2.068                        | 239.9              | 1.495                        | 4.596                                  | 4.107                        |
| 104.                       | 22.52                                  | 2.268                        | 204.1              | 1.610                        | 3.613                                  | 4.518                        |
| 158.                       | 13.84                                  | 2.593                        | 149.8              | 1.866                        | 2.507                                  | 5.274                        |
| 203.                       | 8.347                                  | 2.941                        | 113.1              | 2.052                        | 1.656                                  | 5.473                        |
| 248.                       | 4.265                                  | 3.306                        | 79.62              | 2.369                        | .7900                                  | 5.565                        |
| 284.                       | 2.263                                  | 3.840                        | 49.92              | 2.574                        | 1.635                                  | 6.711                        |
| WL239.                     | 52.35                                  | 1.634                        | 316.2              | 1.449                        | 16.71                                  | 2.238                        |

CONDITION 6B YD  
LATERAL ANALYSIS

# CONDITION 1B LATERAL ANALYSIS

GW 214,400. LB. SPEED: 505 KT.  
 ALT. 42,000 FT. V<sub>1</sub> 239 KT.  
 CG 214 PERCENT MAC V<sub>0</sub> M .90

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                       |                  | SHEAR              |                  | TORSION                              |                  |
|----------------------------|--------------------------------------|------------------|--------------------|------------------|--------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. |
| 820.                       | 241.4                                | 1.755            | 327.3              | 2.142            | 69.97                                | 1.262            |
| 1020                       | 175.8                                | 1.610            | 342.4              | 2.123            | 70.57                                | 1.187            |
| 1220.                      | 91.13                                | .8507            | 380.8              | 1.458            | 70.07                                | 1.094            |
| 1335                       | 51.52                                | .9735            | 390.6              | 1.190            | 68.91                                | 1.093            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                       |                  | SHEAR              |                  | TORSION                              |                  |
|----------------------------|--------------------------------------|------------------|--------------------|------------------|--------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. |
| 67.                        | 39.42                                | 1.263            | 315.3              | .7944            | 5.435                                | 2.015            |
| 104.                       | 29.02                                | 1.420            | 267.0              | .8913            | 4.098                                | 2.331            |
| 158.                       | 17.34                                | 1.680            | 193.2              | 1.117            | 2.557                                | 3.109            |
| 203.                       | 10.07                                | 1.982            | 145.4              | 1.255            | 1.536                                | 3.665            |
| 248.                       | 4.900                                | 2.331            | 100.5              | 1.510            | 6.690                                | 4.008            |
| 284.                       | 2.381                                | 2.961            | 59.5               | 1.624            | 13.31                                | 4.983            |
| WL239                      | 68.62                                | .9097            | 420.3              | .6893            | 20.80                                | 1.446            |

CONDITION 1B

LATERAL ANALYSIS

# CONDITION 2B LATERAL ANALYSIS

GW 214,400 LB. SPEED: 519 KT.  
 ALT. 35,000 FT.  $V_7$  289 KT.  
 CG 21.4 PERCENT MAC  $V_6$  M .90

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                       |                  | SHEAR             |                  | TORSION                              |                  |
|----------------------------|--------------------------------------|------------------|-------------------|------------------|--------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. |
| 820.                       | 273.9                                | 1.814            | 374.7             | 2.241            | 78.96                                | 1.427            |
| 1020.                      | 199.2                                | 1.657            | 391.0             | 2.213            | 79.44                                | 1.337            |
| 1220.                      | 102.0                                | .9583            | 432.1             | 1.501            | 78.72                                | 1.224            |
| 1335                       | 57.43                                | 1.077            | 442.4             | 1.225            | 77.39                                | 1.222            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                       |                  | SHEAR             |                  | TORSION                              |                  |
|----------------------------|--------------------------------------|------------------|-------------------|------------------|--------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN LB | No.,<br>PER SEC. |
| 67.                        | 43.84                                | 1.418            | 354.3             | .8898            | 6.176                                | 1.954            |
| 104.                       | 32.23                                | 1.601            | 298.7             | .9986            | 4.655                                | 2.226            |
| 158.                       | 19.26                                | 1.905            | 214.6             | 1.249            | 2.983                                | 2.959            |
| 203.                       | 11.22                                | 2.253            | 160.5             | 1.423            | 1.755                                | 3.598            |
| 248.                       | 5.508                                | 2.642            | 110.7             | 1.723            | .7756                                | 3.946            |
| 284.                       | 2.715                                | 3.288            | 65.18             | 1.868            | 1.435                                | 4.040            |
| WL239.                     | 76.80                                | 1.023            | 476.1             | .7962            | 23.138                               | 1.616            |

CONDITION 2B  
LATERAL ANALYSIS

# CONDITION 3B LATERAL ANALYSIS

GW 214,400 LB. SPEED: 528 KT.  
ALT. 30,500 FT.  $V_7$  320 KT.  
CG 21.4 PERCENT MAC  $V_6$  M 90

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 308.3                                  | 1.986            | 426.5              | 2.381            | 93.72                                  | 1.347            |
| 1020.                      | 223.4                                  | 1.712            | 443.1              | 2.325            | 92.00                                  | 1.344            |
| 1220.                      | 114.0                                  | 1.046            | 483.4              | 1.551            | 88.67                                  | 1.304            |
| 1335.                      | 64.26                                  | 1.115            | 493.4              | 1.259            | 87.14                                  | 1.314            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 49.53                                  | 1.512            | 396.3              | .9812            | 7.134                                  | 2.781            |
| 104.                       | 36.53                                  | 1.695            | 335.1              | 1.094            | 5.448                                  | 3.170            |
| 158.                       | 21.94                                  | 2.001            | 242.1              | 1.344            | 3.522                                  | 4.048            |
| 203.                       | 12.85                                  | 2.352            | 181.8              | 1.508            | 2.201                                  | 4.521            |
| 248.                       | 6.334                                  | 2.745            | 126.0              | 1.802            | .963                                   | 4.799            |
| 284.                       | 3.151                                  | 3.407            | 74.37              | 1.947            | 1.995                                  | 5.951            |
| WL 239.                    | 86.196                                 | 1.113            | 530.6              | .8936            | 26.19                                  | 1.717            |

# CONDITION 3B

## LATERAL ANALYSIS

# CONDITION 4B LATERAL ANALYSIS

GW 214,400. LB.      SPEED:      V<sub>Y</sub> 344 KT.  
 ALT. 23,500. FT.      V<sub>6</sub> 374. KT.  
 CG 214 PERCENT MAC      M 9

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 361.9                                  | 1.903            | 503.5              | 2.449            | 110.1                                  | 1.327            |
| 1020                       | 262.3                                  | 1.720            | 520.6              | 2.373            | 108.0                                  | 1.325            |
| 1220.                      | 133.9                                  | 1.077            | 568.5              | 1.545            | 104.0                                  | 1.286            |
| 1335.                      | 78.09                                  | 1.150            | 530.9              | 1.252            | 102.2                                  | 1.294            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 57.47                                  | 1.451            | 466.7              | 1.026            | 8.478                                  | 3.184            |
| 104.                       | 42.17                                  | 1.615            | 393.1              | 1.115            | 6.460                                  | 3.610            |
| 158                        | 25.13                                  | 1.903            | 281.6              | 1.313            | 4.129                                  | 4.596            |
| 203.                       | 14.60                                  | 2.245            | 210.0              | 1.456            | 2.547                                  | 5.066            |
| 248.                       | 7.131                                  | 2.649            | 144.3              | 1.721            | 1.154                                  | 5.316            |
| 284.                       | 3.503                                  | 3.354            | 84.69              | 1.885            | 2.360                                  | 6.853            |
| WL 239.                    | 101.1                                  | 1.128            | 628.6              | .9885            | 30.20                                  | 1.630            |

CONDITION 4B  
LATERAL ANALYSIS

# CONDITION 5B LATERAL ANALYSIS

GW 214,400 LB. SPEED: 495 KT.  
ALT. 18,000 FT.  $V_7$  374 KT.  
CG 214 PERCENT MAC  $V_8$  M .80

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 343.5                                  | 1.870            | 475.0              | 2.372            | 99.60                                  | 1.525            |
| 1020.                      | 249.3                                  | 1.696            | 491.6              | 2.329            | 100.2                                  | 1.418            |
| 1220.                      | 127.2                                  | 1.069            | 540.6              | 1.526            | 99.07                                  | 1.286            |
| 1335.                      | 71.46                                  | 1.144            | 553.1              | 1.240            | 97.37                                  | 1.281            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 54.91                                  | 1.424            | 444.9              | 1.001            | 8.075                                  | 3.111            |
| 104.                       | 40.32                                  | 1.587            | 375.0              | 1.088            | 6.151                                  | 3.529            |
| 158.                       | 24.04                                  | 1.869            | 269.2              | 1.286            | 3.924                                  | 4.491            |
| 203.                       | 13.96                                  | 2.204            | 201.1              | 1.429            | 2.418                                  | 4.968            |
| 248.                       | 6.819                                  | 2.596            | 138.3              | 1.690            | 1.101                                  | 5.266            |
| 284.                       | 3.337                                  | 3.286            | 81.24              | 1.848            | 2.213                                  | 6.706            |
| WL239.                     | 94.46                                  | 1.103            | 598.3              | .9610            | 29.86                                  | 1.606            |

CONDITION 5B

LATERAL ANALYSIS

# CONDITION 6B LATERAL ANALYSIS

GW 214,400 LB. ALT. 15,000 FT. CG 21.4 PERCENT MAC

SPEED: V<sub>4</sub> 473 KT. V<sub>6</sub> 375 KT. M .76

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 320.                       | 292.6                                  | 1.763                        | 402.6              | 2.200                        | 85.00                                  | 1.394                        |
| 1020.                      | 212.3                                  | 1.608                        | 415.3              | 2.186                        | 85.61                                  | 1.299                        |
| 1220.                      | 109.4                                  | .9831                        | 462.0              | 1.449                        | 84.79                                  | 1.182                        |
| 1335.                      | 61.58                                  | 1.065                        | 473.7              | 1.186                        | 83.32                                  | 1.179                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 67.                        | 47.13                                  | 1.324                        | 380.9              | .9152                        | 6.784                                  | 2.803                        |
| 104.                       | 34.63                                  | 1.479                        | 321.5              | .9975                        | 5.151                                  | 3.190                        |
| 158.                       | 20.63                                  | 1.746                        | 231.2              | 1.190                        | 3.282                                  | 4.094                        |
| 203.                       | 11.46                                  | 2.062                        | 172.9              | 1.327                        | 1.988                                  | 4.586                        |
| 248.                       | 5.824                                  | 2.435                        | 119.0              | 1.576                        | .9017                                  | 4.904                        |
| 284.                       | 2.819                                  | 3.101                        | 70.05              | 1.719                        | 1.766                                  | 6.268                        |
| WL239.                     | 82.62                                  | 1.013                        | 510.8              | .8289                        | 24.819                                 | 1.505                        |

CONDITION 6B  
LATERAL ANALYSIS

# CONDITION 10A LATERAL ANALYSIS

GW 204,000. LB. SPEED: 475. KT.  
 ALT. 35,000. FT.  $V_f$  280. KT.  
 CG 21.5 PERCENT MAC  $V_0$  M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 223.2                                  | 1.824            | 303.2              | 2.242            | 69.52                                  | 1.201            |
| 1020.                      | 163.5                                  | 1.648            | 320.6              | 2.209            | 68.42                                  | 1.199            |
| 1220.                      | 82.66                                  | .9097            | 356.7              | 1.507            | 66.08                                  | 1.164            |
| 1335                       | 46.81                                  | 1.039            | 365.5              | 1.220            | 64.95                                  | 1.168            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         | 37.13                                  | 1.354            | 296.9              | .8592            | 5.271                                  | 2.233            |
| 104.                       | 27.43                                  | 1.519            | 250.9              | .9619            | 4.001                                  | 2.561            |
| 158.                       | 16.48                                  | 1.793            | 182.1              | 1.195            | 2.549                                  | 3.323            |
| 203.                       | 9.649                                  | 2.103            | 137.3              | 1.341            | 1.562                                  | 3.809            |
| 248                        | 4.746                                  | 2.455            | 95.32              | 1.608            | .6887                                  | 4.101            |
| 284                        | 2.332                                  | 3.057            | 56.52              | 1.729            | 1.404                                  | 5.033            |
| HL239.                     | 64.42                                  | .9811            | 394.7              | .7592            | 1.961                                  | 1.507            |

# CONDITION 10A LATERAL ANALYSIS



# CONDITION 10B LATERAL ANALYSIS

GW 204,000. LB. SPEED: 475. KT.  
ALT. 35,000. FT.  $V_4$  280. KT.  
CG 21.5 PERCENT MAC  $V_6$  M  
M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 239.4                                  | 1.710            | 322.7              | 2.177            | 75.76                                  | 1.100            |
| 1020                       | 173.8                                  | 1.559            | 340.6              | 2.090            | 74.52                                  | 1.107            |
| 1220.                      | 90.69                                  | .8835            | 385.3              | 1.403            | 71.99                                  | 1.075            |
| 1335.                      | 51.27                                  | .9539            | 397.0              | 1.139            | 70.75                                  | 1.079            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         | 40.35                                  | 1.253            | 323.2              | .7912            | 5.662                                  | 2.083            |
| 104.                       | 29.74                                  | 1.410            | 273.8              | .8865            | 4.281                                  | 2.398            |
| 158.                       | 17.80                                  | 1.670            | 198.2              | 1.105            | 2.688                                  | 3.158            |
| 203                        | 10.36                                  | 1.968            | 149.1              | 1.242            | 1.626                                  | 3.669            |
| 248.                       | 5.064                                  | 2.312            | 103.2              | 1.493            | .7115                                  | 3.981            |
| 284                        | 2.454                                  | 2.919            | 61.08              | 1.609            | 1.421                                  | 4.982            |
| VL239                      | 70.29                                  | .9041            | 431.6              | .6984            | 21.28                                  | 1.396            |

CONDITION 10B  
LATERAL ANALYSIS

# CONDITION 10C LATERAL ANALYSIS

GW 204,000 LB. SPEED: 475 KT.  
 ALT. 35,000 FT.  $V_7$  280. KT.  
 CG 21.5 PERCENT MAC  $V_6$  M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                     | SHEAR              |                     | TORSION                |                     |
|----------------------------|----------------------------------------|---------------------|--------------------|---------------------|------------------------|---------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | $N_0$ ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | $N_0$ ,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | $N_0$ ,<br>PER SEC. |
| 820.                       | 246.0                                  | 1.667               | 330.6              | 2.070               | 78.29                  | 1.076               |
| 1020.                      | 180.8                                  | 1.518               | 348.7              | 2.043               | 77.01                  | 1.074               |
| 1220.                      | 93.94                                  | .8062               | 396.9              | 1.346               | 74.40                  | 1.043               |
| 1336.                      | 53.08                                  | .9226               | 409.8              | 1.105               | 73.11                  | 1.046               |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                     | SHEAR              |                     | TORSION                                |                     |
|----------------------------|----------------------------------------|---------------------|--------------------|---------------------|----------------------------------------|---------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | $N_0$ ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | $N_0$ ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | $N_0$ ,<br>PER SEC. |
| 67.                        | 41.66                                  | 1.216               | 334.9              | .7667               | 5.823                                  | 2.026               |
| 104.                       | 30.63                                  | 1.369               | 283.1              | .8592               | 4.396                                  | 2.336               |
| 158.                       | 18.34                                  | 1.624               | 204.7              | 1.072               | 2.746                                  | 3.094               |
| 203.                       | 10.66                                  | 1.917               | 154.0              | 1.205               | 1.653                                  | 3.612               |
| 248.                       | 5.195                                  | 2.258               | 106.4              | 1.430               | .7210                                  | 3.933               |
| 284.                       | 2.505                                  | 2.866               | 62.95              | 1.564               | 1.428                                  | 4.961               |
| 41239.                     | 72.68                                  | .8760               | 446.7              | .6765               | 21.96                                  | 1.355               |

CONDITION 10C

LATERAL ANALYSIS

# CONDITION 100 LATERAL ANALYSIS

GW 204,000. LB. SPEED: V<sub>r</sub> 475. KT.  
ALT. 35,000. FT. V<sub>0</sub> 280. KT.  
CG 21.5 PERCENT MAC M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 820.                       | 249.5                                  | 1.640                        | 332.5              | 2.052                        | 80.84                  | 1.040                        |
| 1020.                      | 184.0                                  | 1.488                        | 351.3              | 2.024                        | 79.57                  | 1.038                        |
| 1220.                      | 96.92                                  | .7831                        | 405.3              | 1.333                        | 76.90                  | 1.008                        |
| 1338.                      | 54.68                                  | .8969                        | 420.5              | 1.076                        | 75.58                  | 1.012                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 67.                        | 43.06                                  | 1.174                        | 346.4              | .7416                        | 6.033                                  | 1.955                        |
| 104.                       | 31.69                                  | 1.322                        | 293.2              | .8303                        | 4.546                                  | 2.257                        |
| 158.                       | 18.91                                  | 1.571                        | 211.8              | 1.035                        | 2.823                                  | 3.006                        |
| 203.                       | 10.97                                  | 1.858                        | 159.3              | 1.163                        | 1.688                                  | 3.532                        |
| 248.                       | 5.330                                  | 2.194                        | 109.9              | 1.402                        | .7323                                  | 3.864                        |
| 284.                       | 2.553                                  | 2.802                        | 65.02              | 1.511                        | 1.438                                  | 4.923                        |
| WL239.                     | 75.26                                  | .8472                        | 463.0              | .6552                        | 22.67                                  | 1.310                        |

CONDITION 100  
LATERAL ANALYSIS

# CONDITION 10E LATERAL ANALYSIS

GW 204,000. LB. SPEED: 475. KT.  
ALT. 35,000. FT. V<sub>4</sub> 280. KT.  
CG 21.5 PERCENT MAC V<sub>6</sub> M  
M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 820.                       | 225.7                                  | 1,600                        | 339.2              | 2,012                        | 836.7                  | 1,007                        |
| 1020.                      | 189.0                                  | 1,450                        | 358.4              | 1,984                        | 82.37                  | 1,004                        |
| 1220.                      | 100.5                                  | .7575                        | 417.2              | 1,296                        | 79.62                  | .9747                        |
| 1335.                      | 55.63                                  | .8672                        | 434.1              | 1,044                        | 78.26                  | .9779                        |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                              | SHEAR              |                              | TORSION                                |                              |
|----------------------------|----------------------------------------|------------------------------|--------------------|------------------------------|----------------------------------------|------------------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>LB. | N <sub>0</sub> ,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | N <sub>0</sub> ,<br>PER SEC. |
| 67.                        | 44.57                                  | 1,137                        | 359.1              | .7173                        | 6.232                                  | 1.393                        |
| 104.                       | 32.77                                  | 1,280                        | 303.9              | .8030                        | 4.689                                  | 2.189                        |
| 158.                       | 19.53                                  | 1,552                        | 219.4              | 1,022                        | 2.897                                  | 2.931                        |
| 203.                       | 11.41                                  | 1,804                        | 164.9              | 1,126                        | 1.722                                  | 3.463                        |
| 248.                       | 5.480                                  | 2,136                        | 113.6              | 1,357                        | .7442                                  | 3.804                        |
| 284.                       | 2.610                                  | 2,742                        | 67.19              | 1,463                        | 1.447                                  | 4.891                        |
| WL 239.                    | 78.00                                  | .8191                        | 480.3              | .6338                        | 23.44                                  | 1.268                        |

CONDITION 10E

LATERAL ANALYSIS

# CONDITION 10F LATERAL ANALYSIS

GW 204,000. LB.      SPEED:      V<sub>7</sub> 475. KT.  
ALT. 35,000. FT.      V<sub>6</sub> 280. KT.  
CG 21.5 PERCENT MAC      M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | No.,<br>PER SEC. |
| 820                        | 293.5                                  | 1.446            | 369.3              | 1.850            | 95.94                  | .8833            |
| 1020                       | 211.0                                  | 1.302            | 390.4              | 1.823            | 94.50                  | .8808            |
| 1220                       | 115.6                                  | .6650            | 469.3              | 1.156            | 91.39                  | .8552            |
| 1335                       | 65.01                                  | .7616            | 493.1              | .9234            | 89.84                  | .8576            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         | 51.06                                  | .9964            | 413.9              | .6298            | 70.97                                  | 1.665            |
| 104                        | 37.45                                  | 1.124            | 350.0              | .7039            | 5.313                                  | 1.945            |
| 158                        | 22.21                                  | 1.341            | 251.9              | .8768            | 3.220                                  | 2.638            |
| 203                        | 12.77                                  | 1.600            | 189.1              | .9859            | 1.873                                  | 3.184            |
| 248                        | 6.137                                  | 1.909            | 129.7              | 1.192            | .7971                                  | 3.552            |
| 284                        | 2.864                                  | 2.501            | 76.59              | 1.287            | 1.490                                  | 4.751            |
| WL239                      | 89.81                                  | .7179            | 554.4              | .5576            | 26.79                                  | 1.114            |

CONDITION 10F  
LATERAL ANALYSIS

# CONDITION 10G LATERAL ANALYSIS

GW 204,000. LB. SPEED: 475. KT.  
ALT. 35,000. FT. V<sub>4</sub>  
CG 21.5 PERCENT MAC V<sub>6</sub> 280. KT.  
M .02

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 820.                       | 246.1                                  | 1.664            | 329.7              | 2.075            | 79.17                                  | 1.062            |
| 1020.                      | 181.5                                  | 1.513            | 348.2              | 2.046            | 77.91                                  | 1.060            |
| 1220.                      | 94.89                                  | .7992            | 399.0              | 1.357            | 75.29                                  | 1.029            |
| 1335.                      | 53.57                                  | .9153            | 412.9              | 1.098            | 73.99                                  | 1.032            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67.                        | 42.17                                  | 1.199            | 338.8              | .7574            | 8.911                                  | 1.995            |
| 104.                       | 31.05                                  | 1.350            | 286.8              | .8480            | 4.459                                  | 2.302            |
| 158                        | 18.54                                  | 1.602            | 207.3              | 1.057            | 2.779                                  | 3.055            |
| 203.                       | 10.77                                  | 1.893            | 156.0              | 1.188            | 1.668                                  | 3.576            |
| 248                        | 5.242                                  | 2.233            | 107.7              | 1.430            | .7255                                  | 3.903            |
| 284                        | 2.521                                  | 2.841            | 63.72              | 1.524            | 1.443                                  | 4.940            |
| WL239.                     | 73.63                                  | .8656            | 45.27              | .6600            | 22.21                                  | 1.338            |

CONDITION 10G  
LATERAL ANALYSIS

# CONDITION 10 H LATERAL ANALYSIS

GW 204,000. LB.      SPEED:      475. KT.  
ALT. 35,000. FT.       $V_f$       280. KT.  
CG 21.5 PERCENT MAC       $V_G$       M .82

## FUSELAGE

| BODY<br>BALANCE<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>IN. LB. | No.,<br>PER SEC. |
| 820                        | 254.6                                  | 1.650            | 338.8              | 2.067            | 82.75                  | 1.041            |
| 1020                       | 188.0                                  | 1.496            | 357.8              | 2.039            | 91.44                  | 1.039            |
| 1220                       | 99.37                                  | .7827            | 414.4              | 1.340            | 78.72                  | 1.009            |
| 1335                       | 56.05                                  | .8966            | 430.3              | 1.080            | 77.37                  | 1.012            |

## VERTICAL TAIL

| ELASTIC<br>AXIS<br>STATION | BENDING MOMENT                         |                  | SHEAR              |                  | TORSION                                |                  |
|----------------------------|----------------------------------------|------------------|--------------------|------------------|----------------------------------------|------------------|
|                            | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>LB. | No.,<br>PER SEC. | $\bar{A}$ ,<br>10 <sup>3</sup> IN. LB. | No.,<br>PER SEC. |
| 67                         | 44.06                                  | 1.178            | 354.8              | -.7437           | 6.159                                  | 1.964            |
| 104                        | 32.41                                  | 1.327            | 300.3              | .8412            | 4.637                                  | 2.270            |
| 158                        | 19.32                                  | 1.577            | 216.8              | 1.038            | 2.870                                  | 3.033            |
| 203                        | 11.19                                  | 1.869            | 163.0              | 1.168            | 1.709                                  | 3.577            |
| 248                        | 5.430                                  | 2.210            | 112.4              | 1.407            | .740                                   | 3.922            |
| 284                        | 2.592                                  | 2.832            | 66.44              | 1.599            | 1.495                                  | 5.024            |
| WL239                      | 77.07                                  | .8494            | 474.4              | .6569            | 23.19                                  | 1.315            |

CONDITION 10 H  
LATERAL ANALYSIS